Table 4.23 Performance results with 1 percent trading band and trailing 20-day stop

Market	Profit ($)	Winners; Total Trades	Percentage of Winne	Ratio: Average Win/	Profit Factor	Maximum Intraday Drawdow
British pound	146,544	47; 93	51	2.39	2.44	-17,319
Coffee	242.119	47:118	40	3.84	2.49	-26.970
Cotton	58.1 35	46:100	46	2.21	1.56	-19.160
Crude oil	4.740	28: 69	39	0.73	1.11	-8.020
Deutsche	69.526	48: 94	51	1.90	1.98	-10.425
Gold	29.360	41: 112	37	2.29	1.32	-27.1 70
Heating oil	44.177	42:101	42	2.11	1.50	-26.879
Japanese	99.400	46: 87	53	2.32	2.60	-11.338
Live hogs	53.768	57: 108	53	1.88	2.10	-9.376
Soybeans	45.688	44: 116	38	2.58	1.57	-19.275
S&P-500	-25.955	25:105	23	2.44	0.73	-79.710
Swiss franc	80.338	50: 101	50	1.97	1.93	-9.188
10-vear T-note	37.768	22: 58	38	2.60	1.65	-5.206
U.S. bond	57.100	35: 90	39	2.28	1.5	-16.075
Average	67,336		43	2.25	1.75	-20,437

crop failure, to name just a few of the types of events you can read about in the financial press. In a purely technical sense, you do not need the confirmation from fundamental analysis. However, if unusual fundamental conditions exist, that may give you clues as to the probable duration and potential amplitude of possible market movements, and help you determine how you could adjust the size of your position.

Summary

In this chapter we examined seven major systems, each exploring a different philosophy. The 65sma-3cc system is a simple trend-following system that offers solid performance. We examined this system in great detail. You should perform such a detailed analysis of your systems. We used many important ideas such as maximum favorable and adverse excursions, frequency distribution of trades, and the effect of a volatility-

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based initial stop. *You* should endeavor to understand these ideas and use them often. In summary, the 65sma-3cc system was a robust and profitable system that makes money in trending periods. About 4 percent of the trades were mega-trades, and you should pick your exit strategies carefully so as not to cut off such trades prematurely.

The channel breakout-pull back (CB-PB) system was our first pattern-based system for long trades. The system gives reliable long entries; it was profitable about 55 percent of the time without stops or exits over many markets. Our tests with different exit strategies found that the CB-PB system provides low-risk entries and can be easily adapted to many trading styles. CB-PB does well in short- to intermediate-term systems on active markets. In summary, we showed how we can develop very different systems of the same entry signal.

The ADX burst trend-seeking system uses a filter based on the strength of the trend. It successfully provides entries into strong trends. The system has a large neutral zone so it is in the market only 35 to 45 percent of the time.

We next looked at the trend-antitrend (T-AT) system, which automatically switches between antitrend and trend-following modes. This system often picks tops and bottoms with surprising accuracy. It is essential to use good risk control with a system such as this because the volatility can trap you on the wrong side of the market.

The gold-bond system allows us to use intermarket analysis on positively or negatively correlated markets. This system tries to capture weak intermarket relationships. It can be used with or without a trend filter. We found several interesting relationships between the U.S. bond market and the gold, copper, soybeans, and currency markets. We extended the gold bond system to look at correlated markets such as deutsche mark-Japanese yen and corn-live hogs. At a minimum, you can use this system to evaluate a favorable or unfavorable background for your trading.

The bottom-fishing pattern started off as a market-specific system for trading the S&P-500 futures. We found that the pattern can be generalized to other markets, as well as to stocks. The pattern also works on daily, weekly, or monthly data. Thus, we captured a fundamental feature of price behavior in markets with this pattern.

The extraordinary opportunity system is primarily a flag to vary bet size during trading. It is an effective trend-following system in its own right. It assumes that during major moves, a significant portion of the move will be outside 1-percent or 3-percent trading bands drawn around a 50-day SMA.

You will notice that we did not follow the usual practice of dividing the test period into two or more subintervals, "perfecting" our system on one interval, and then testing it on the remaining data. This procedure exposes the system to new data, and its performance on such "out-of-sample" data is used to determine how well it might work in the future. If you do test many combinations of parameters, try to find the most "stable" combination. Stability means that the system is profitable across most of the test data, and results do not change suddenly for small variations in test conditions. A detailed discussion of this approach is found in Babcock, Chande and Kroll, Pardo, and Schwager among others (see bibliography).

Instead of relying on testing alone, here we have focused on the ideas driving the trading strategy. We tested these systems on all available data over 20 years without optimization. Thus, we stressed our systems to check if they were based on valid market dynamics that can be tapped for future trading profits. These systems are examples of the art of building new strategies around a particular market intuition. In the next chapter we examine how you can modify well-known, proven ideas to create useful variations for your collection of trading systems.

Chapter

Developing Trading System Variations

Even change is never the same.

Introduction

This chapter explores how you can take existing ideas and then develop variations that suit your trading style. In this way, you can build a large collection of trading systems that meet different objectives. Every trader has different beliefs, time horizons, equity limitations, profit objectives, and confidence levels. Hence, few traders are executing precisely the same strategy. Thus you can trade even well-known systems without much difficulty. However, you can gain an edge by developing your variations of well-known ideas. As usual, this is not a recommendation of specific ideas for trading, but an attempt to stimulate your creativity. The focus should be on how each variation changes the structure of the trading system and its response to market data.

We first consider the 20-day or 4-week breakout system, perhaps one of the oldest mechanical trading systems in the business. We set the stage by looking at the results of a 20-bar breakout on the close using two different exit strategies. One exit strategy is a simple a"-day trailing exit, but the other is a more complex volatility-based exit. The first variation is using a fixed barrier above the 20-day range. The next step, after

a fixed barrier, is to consider systems with a variable or volatility-based barrier.

In an interesting twist, instead of adding, we will deduct a volatility-based "barrier" from the 20-day channel, and examine the statistical significance of these channel breakout variations. All these variations should convince you that it is possible to take a proven idea and then adapt it to your needs or trading style.

We then look at two models based on the ADX indicator. The average directional index measures the strength of price trends. You will see that the heavily smoothed ADX reduces trades without missing major trends. We first test the effects of using a fixed ADX level to trigger the trades, and next, impose the restriction that the ADX be rising. You will see that the absolute level of the ADX is not as significant as its trend.

You may have heard this bit of trading advice, "Buy on a pullback into support." This advice by itself is not sufficient to build a trading system, but we will discuss a pullback system that works in uptrends as well as downtrends.

This chapter ends with a pattern-based system for long entries only. The deep pass in football inspired the "long bomb" system. With this system you can gather useful patterns off your favorite charts.

We will test these systems without optimization. Model values are chosen at random, before any testing, so that the test results do not bias the selection. The systems are tested on the same data set so you can understand the subtle interactions between system rules and market action. You should try to develop your variations of well-known ideas to find the particular combinations that best suit your trading style and meet your goals.

Table 5.1 Summary of markets and test periods used in this chapter

Market	Test Period

British pound	2/75-7/95
Coffee	1/75-7/95
Crude oil	1/83-7/95
Cotton	1/75-7/95
Deutsche mark	1/75-7/95
Eurodollar	2/75-7/95
Gold	2/75-7/95
Japanese yen U.S. bond Wheat	2/82-7/95
	1/75-7/95
	8/76-7/95
	8/77-7/95
	1/75-7/95

We chose the markets in Table 5.1 for testing simply because they represent a diverse group that had shown strong trends, periods of volatility, and many consolidations. The tests used an initial stop of $1,500 and allowed $100 for slippage and commissions.

Channel Breakout on Close with Trailing Stops

We begin by examining the effect of adding a trailing stop to the usual channel breakout system. Our purpose is to convert the channel breakout logic into a short-term trading system. The logic of the channel breakout on close is probably familiar to you. The symmetrical long and short entry rules are as follows:

1. If today's close is higher than the highest high of the last 20 days, then buy on the close.
2. If today's close is lower than the lowest low of the last 20 days, then sell on the close.

The exit condition is a simple trailing stop placed at the highest high or lowest low of the last few days. In our case, we want to use a 5-day trailing stop. The exit conditions are as follows:

3. Exit the long trade at the lowest low of the last 5 days on a stop.
4. Exit the short trade at the highest high of the last 5 days on a stop.

We assume that the market will make quick, decisive moves once it breaks out of the 20-day channel. The implication is that we can use a relatively tight trailing stop to protect most of the profits. A close stop works well in markets that make swing moves. Conversely, this close trailing stop will exit too soon during prolonged trends. *You* may see more than one trade during long-trending periods because the system will generate a new trade on a fresh breakout beyond the barrier. Table 5.2 gives the results of the historical tests using a $1,500 initial stop, trading one contract per signal, and allowing $100 for slippage and commissions.

The basic 20-bar breakout system is a typical trend-following system, with 36 percent profitable trades and an average win-loss ratio greater than 2. Sixty-three percent of the profits are from just one market, coffee. The average profit factor (the ratio of gross profit to gross loss) is 1.19, so the system produces slightly more profits than losses.

Table 5.2 Historical results for 20-bar breakout on the close with exit on the 5-day high or low

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/Loss Ratio	Average Trade ($)	Maximum Intraday Draw-down	Profit Factor
British pound	38,869	259	34	2.35	150	-21338	1.21
Coffee	1	255	38	3.26	696	-24.414	2.03
Cotton	-1.300	260	35	1.81	-5	-23.275	0.99
Crude	-	157	29	1.10	-275	-44.230	0.44
Deutsc mark	38.575	229	43	1.86	168	-12.800	1.42
Eurodol	14,225	142	45	1.71	100	-5,175	1.40
Gold	19.180	222	31	2.67	86	-36.870	1.18
Japane ven	64.91	201	44	2.01	323	-11.388	1.56
U.S.	-5.013	222	36	1.71	-23	-35.994	0.96
Wheat	-	248	29	1.61	-97	-32,475	0.67
Total	279,48	2,195					
Averag	27,949	220	36	2.01	112	-24,796	1.19

The average trade at $112 is barely acceptable, partly the result of staying in the trade for only a short time.

The 2,195 total trades suggest that trading costs and slippage are a significant factor in overall performance. Losses in four of the ten markets tested are a bit worrisome. The average profit is not much greater than the average maximum drawdown, which is another concern.

These tests used an exit on the highest high or lowest low of the last 5 days. The 5-day high or low exit strategy assumes that the market will make a strong move after making new 20-day highs. The following two cases show how this exit works in practice. In the case of wheat (see Figure 5.1), the market was in a choppy uptrend. A choppy uptrend is weak, because the market consolidates after making new highs. Our exit on the 5-day high or low closes out the trade in the consolidation region following new highs. Hence, in the choppy uptrend of the wheat market, there is a string of short-lived trades.

The next case (see Figure 5.2), presents the ideal trade for the current exit strategy. The coffee market made a strong move upward once it broke out of the 20-day price range. The first significant correction triggered the trailing stop on the 5-day low. Comparing the two cases,

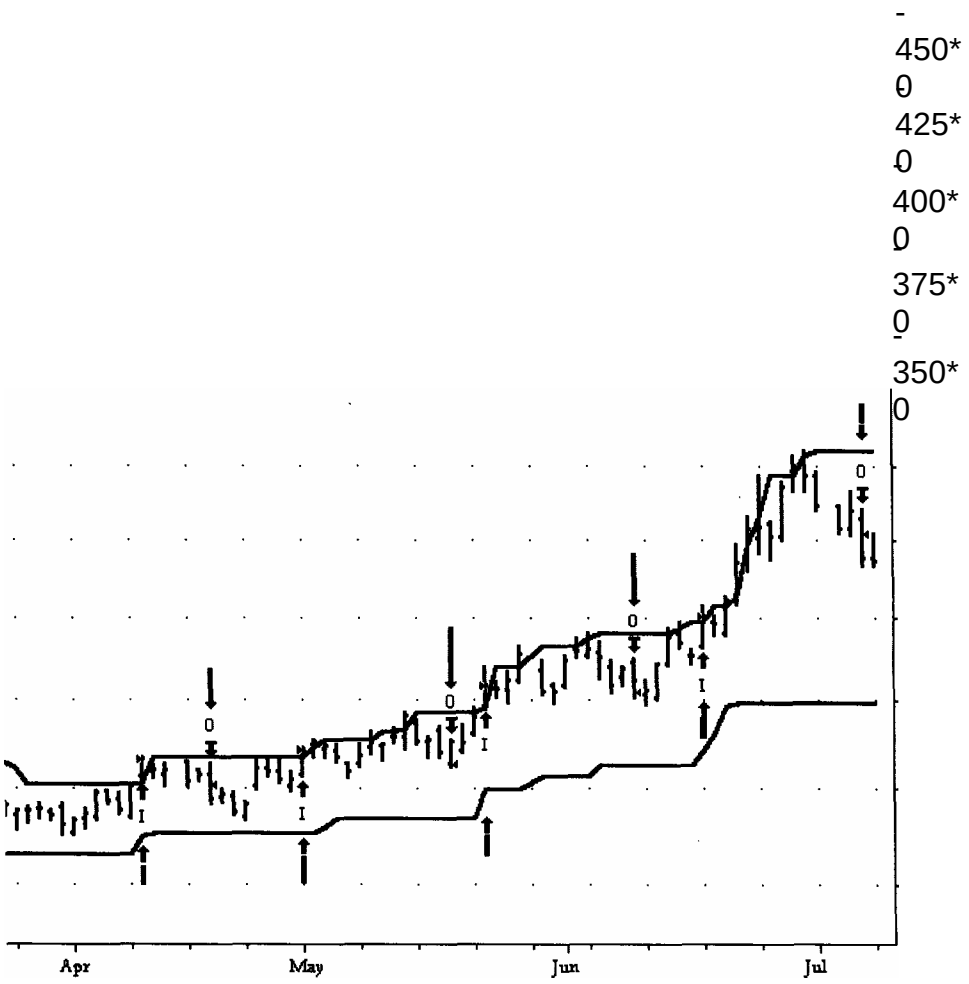

Figure 5.1 The close on the 5-day high or low gives frequent exits in a choppy uptrend in the wheat market.

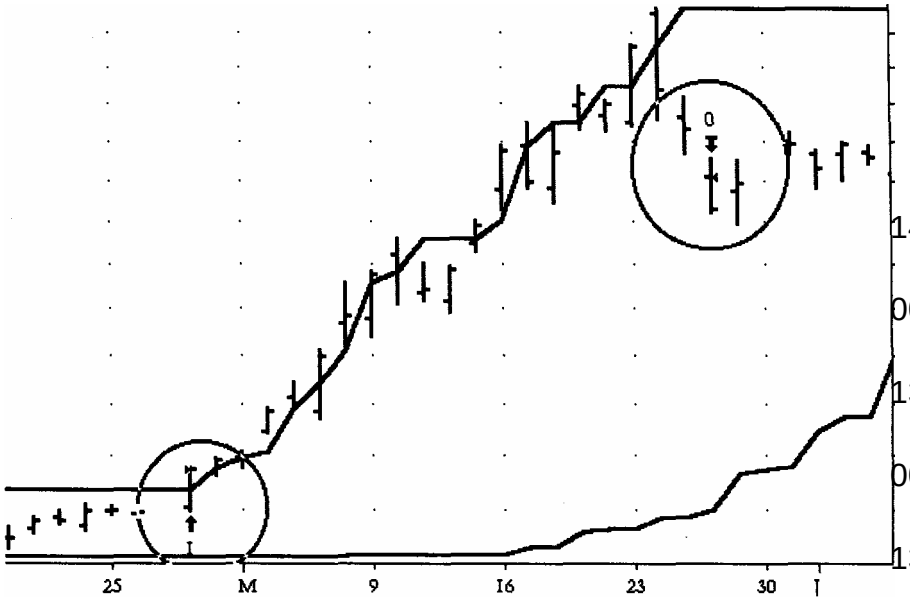

Figure 5.2 The coffee perpetual contract shows ideal market action for the 5-day trailing exit, which works best with markets that move quickly after a breakout.

we see that the trailing exit works best with swing moves. If you wish to use discretion, you should remember this exit strategy in swing markets. The limitation of having to specify the number of days to "look back" to set the trailing stop is not ideal. In the next section we discuss how a volatility-based exit overcomes this limitation.

Channel Breakout on Close with Volatility Exit

Sometimes there is a big move against the established trend when a consolidation is at hand. A volatility criterion can pick off the "big" move against the trend. We want a trailing exit for which we do not have to specify the .r-day look back period. In effect, we will create a volatility-based trailing stop.

There are many different types of volatility-based exits. You can use a 10-day simple moving average of the daily trading range as your measure of volatility. The daily trading range is the difference between the day's high and low. If the market is trading in a narrow range, then the daily range decreases and volatility decreases. However, volatility increases when the market makes large daily moves. For example, near the end of a swing move, the market will often have a wide range day in the direction opposite the trend. The volatility exit closes a trade when there is a large daily move against the trend.

A "large daily move" is defined as three times the volatility, and is called the big move. The big move is added to the most recent 20-day low for short trades, or subtracted from the most recent 20-day high for long trades. This yields a specific price for setting an exit stop. *You* can see the volatility exit for short trades in Figure 5.3.

We can now define the channel breakout system with a volatility exit more precisely. The rules are similar to the usual channel breakout system.

1. If today's close is higher than the highest high of the last 20 days, then buy on the close.
2. Exit the long trade at the highest 20-day high minus three times the 10-day SMA of the daily trading range on a stop.
3. If today's close is lower than the lowest low of the last 20 days, then sell on the close.
4. Exit the short trade at the lowest 20-day low plus three times the 10-day SMA of the daily trading range on a stop.

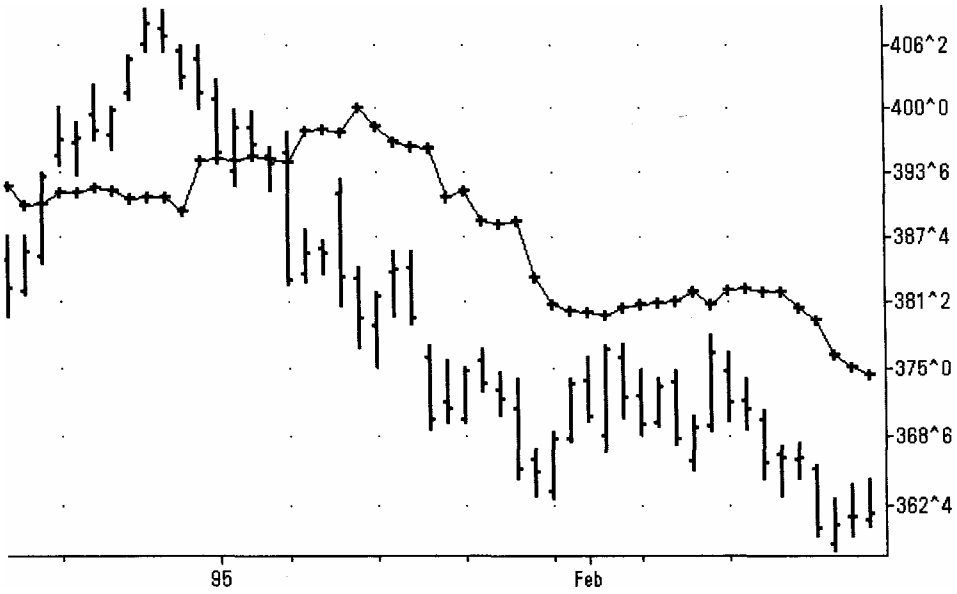

Figure 5.3 The volatility exit for short trades trails prices until a big move or reversal closes out the trade.

For our computer tests, we will use a $1,500 initial stop, trade one contract per signal, and allow $100 for slippage and commissions. We can always trade multiple contracts if we wish. Figure 5.4 shows the volatile uptrend in the August 1995 crude oil contract. The system bought one crude oil contract on the usual 20-bar breakout on the close. A sharp key reversal caused a big down day in the middle of the chart, which closed below the two previous closes. Follow-through selling the next day triggered our volatility exit.

The system went long again after a new 20-bar high. The market failed on the retest of a new high for the move, and the sharp drop in prices again triggered the volatility exit. Note that the exit stop is being set by the 20-day high and the 10-day SMA of the daily range. A market can reach this stop price quickly during volatile moves, or slowly drift down to the stop level. Key reversals often occur near the end of a trend or the beginning of a consolidation.

For example, sudden market moves with an expanded daily range occur where there is a consensus among traders about price levels. The daily range expands because many traders make similar adjustments. Conversely, sometimes there is no news or information to drive the market. Prices can then drift in small increments toward the exit stop. The main advantage of a volatility-based stop is that it adjusts to the trading patterns of the market (see Figure 5.5). Of course, you will exit the trade in either scenario if prices trade through your stop level.

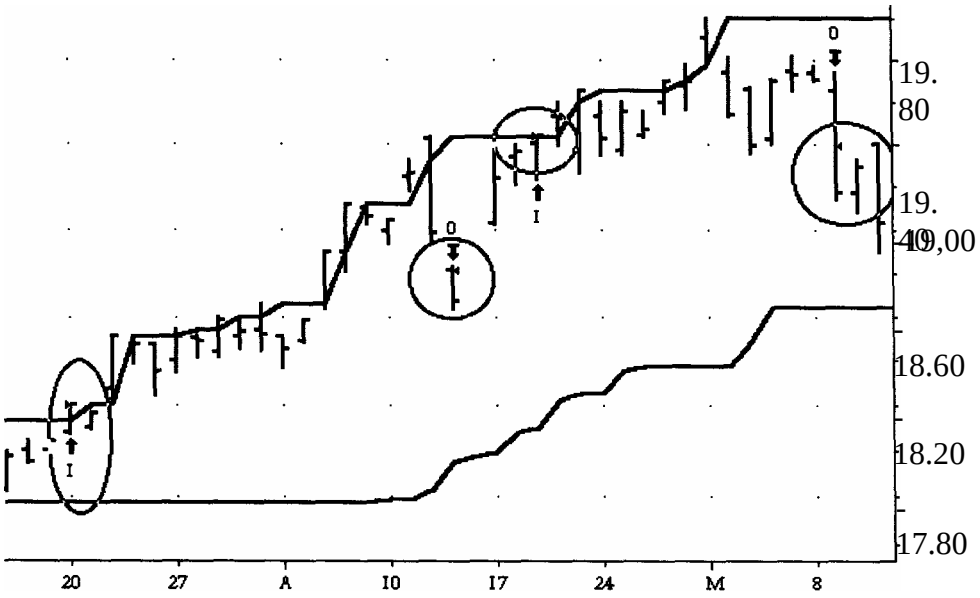

Figure 5.4 Volatility-based exit closes long trades after two big reversals in this crude oil market.

Table 5.3 shows how this exit fared in our tests on past data. These results are a bit better than the tests with a trailing exit on the 5-day high or low (see Table 5.2). The total profits were 25 percent greater using the volatility exit, with 13 percent fewer trades. There were also

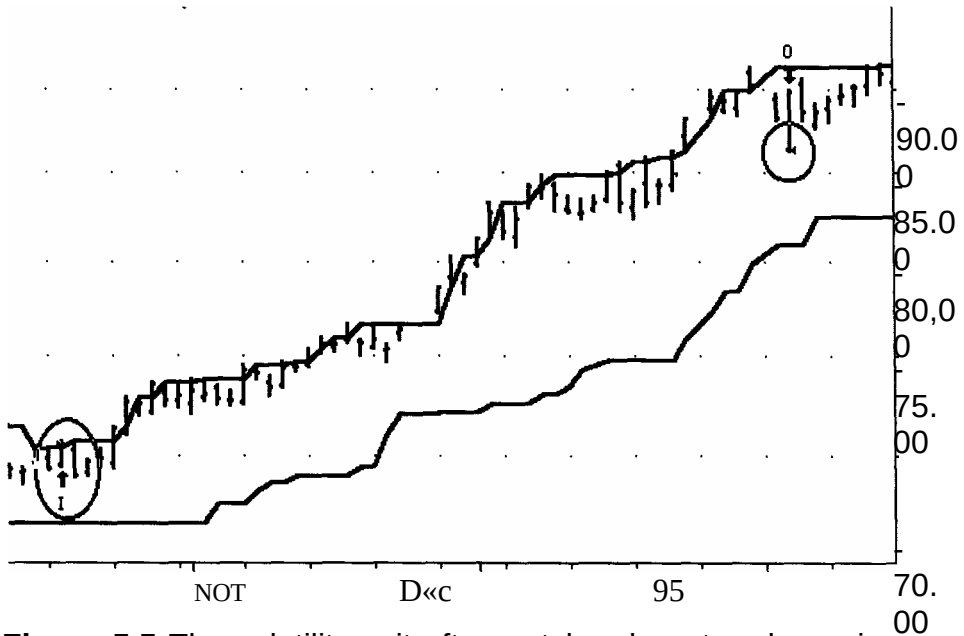

Figure 5.5 The volatility exit often catches long trends, as in the cotton market.

Table 5.3 Results for 20-bar channel breakout with volatility exit

Market	Profit ($)	Number of Trades	Percentage of wins	Wm/ Loss Ratio	Average Trade ($)	Maximu Intraday Draw-down ($)	Profit Factor
British pound	29,650	242	40	1.75	123	-27,331	1.17
Coffee	187.21	222	38	3.15	843	-21.405	2.02
Cotton	27.565	194	35	2.28	143	-18.690	1.23
Crude	-	158	32	0.99	-286	-44.970	0.46
Deutsc mark	51.275	201	45	1.89	255	-9.81 3	1.56
Eurodol	20.925	115	41	2.42	182	-4.775	1.67
Gold	31.170	199	33	2.66	157	-31.430	1.29
Japane yen	59,350	209	43	2.06	284	-12,500	1.53
U.S.	-1.669	182	33	2.01	-10	-28.838	0.99
Wheat	-	187	30	2.00	-54	-19.306	0.85
Total	348,19	1909	37	2.12	164	-21,906	1.28
Avera	7	191					
ge	34,82						
	0						

slight improvements in the profit factor, and a 12 percent reduction in average drawdown. These results are not dramatically different, but the trend toward fewer trades and better profits is worth noting.

So far we have automatically entered a trade just one tick above the 20-day trading range. However, we could reduce the number of trades if we widened the 1-tick barrier. The next section examines the effects of a 20-tick barrier.

Channel Breakout with 20-Tick Barrier

So far our channel breakout on the close stipulated that the close be one tick above the high or low of the previous 20 days. The one tick is simply a barrier level beyond the 20-day trading range. Figure 5.6 uses a 20-tick barrier, instead of the 1-tick barrier. This number is arbitrary; you could certainly test other values. In this case, the decisive close above the barrier led to a strong rally.

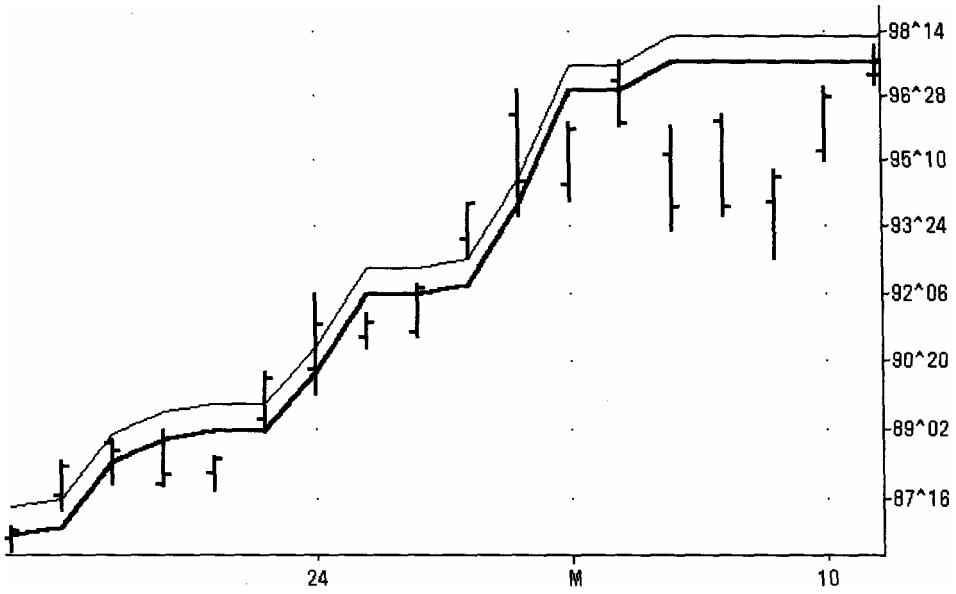

Figure 5.6 The 20-tick barrier for the March 1986 U.S. bond market contract. The thick line is the 20-day high. The narrow line is the 20-tick barrier.

Table 5.4 shows a summary of test results of the system using the volatility exit discussed in the previous section to provide continuity. The initial stop was set at $1,500 and $100 was allowed for slippage and commissions.

The net profit was essentially unchanged compared to the 20-day channel breakout with a volatility exit (see Table 5.3). However, this same profit was achieved with 26 percent fewer trades on average (141 versus 191). The average gain per trade climbed 21 percent, as you would expect with fewer trades. Thus, the main benefit of using a wider barrier is to reduce the total number of trades without hammering profitability.

Note how the results for the U.S. bond market improved from a loss to a profit when we went to a 20-tick barrier. This suggests that many big players are fading the market, say one to ten ticks beyond the previous high or low. Thus, there are many big sellers a few ticks above the previous day's high, and many strong buyers a few ticks below the previous day's low. Only when you clear through this interference does the price change become significant.

Table 5.5, page 158, shows the results of testing the 20-tick barrier system without any exits, and thus clarifies another aspect of the channel break-out system. Remember that not using any exits converts this sys-

tern into a pure trend-following system, with symmetrical entries and exits. Thus, the 20-bar long signal is also the 20-bar short trade exit and vice versa.

The net profits with a barrier but without exits are 50 percent higher with 37 percent fewer trades than with an exit (compare Table 5.4). Surely the basic trend-following system is quite attractive. So it is fair to ask why we should have any exits with the channel breakout. The answer lies in the number of days the systems are in the market, and by implication in the potential risk exposure. If we do not use any exits, the 20-bar breakout system is always in the market. If we add an exit strategy, the system is out of the market some portion of the time. *You* can expect a reduction in exposure to market risk if the system is often out of the market.

Table 5.6 summarizes the number of days the 20-day channel breakout is in the market with and without an exit. Adding the volatility exit reduces the number of days the system is in the market by 58 percent on average. Thus, there is a significant reduction in potential risk when we add an exit to the channel breakout system. Your account could be earning interest when you are out of the market. Your interest income will also help to smooth out account equity.

Table 5.4 Results for the 20-bar channel with a 20-tick barrier and volatility exit.

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/Loss Ratio	Average Trade ($)	Maximum Intraday Drawdown ($)	Profit Factor
British pound	24,588	222	41	1.69	no	-26,888	1.15
Coffee	175.63	213	39	3.04	825	-22.605	1.98
Cotton	27.430	178	35	2.28	154	-18.595	1.25
Crude	^0.630	111	28	1.04	-366	-42.130	0.40
D-Mark	33.275	152	39	2.23	219	-7.813	1.46
Eurodol	2.250	17	41	1.92	132	-2.900	1.34
Gold	31.610	142	32	2.87	222	-25.640	1.38
Japane ven	53.950	161	43	2.08	335	-9.550	1.60
U.S.	29.925	77	38	2.46	388	-20.113	1.49
Wheat	-5,250	137	29	2.17	-38	-15,650	0.89
Total	332,77	1,410					
Averag	33,278	141	37	2.18	198	-19,188	1.29

Table 5.5 Results for the 20-bar channel with a 20-tick barrier and no exit

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/ Loss Ratio	Average Trade ($)	Maximum Intraday Draw-	Profit Factor
British pound	101,64	135	31	3.75	753	-25,544	1.69
Coffee	220.10	144	30	5.46	1.508	-25.224	2.37
Cotton	43.345	114	37	2.94	380	-15.310	1.41
Crude	-1	55	33	1.40	-315	-29.020	0.68
Deutsc mark	49.900	89	38	2.66	561	-10.163	1.64
Eurodol	2,150	10	30	2.78	215	-7,225	1.19
Gold	-6.320	100	30	2.14	-83	-56.940	0.92
Japane ven	74.575	95	35	3.40	785	-12.813	1.81
U.S.	44.400	55	27	4.50	800	-19.825	1.69
Wheat	-12,581	88	30	1.87	-143	-29,494	0.79
Total	499,89	885					
Averag	49,989	89	32	3.09	446	-23,156	1.42

Note that the average maximum intraday drawdown was $19,188 with the volatility exit, versus $23,156 without any exits. Thus, there was also a 17-percent reduction in average drawdown by adding the exit strategy, but this could have occurred purely by chance. Thus, the pri-

Table 5.6 Adding an exit decreases the number of days a system is in the market

Market	Days in Market, No Exits	Days in Market, Volatility Exit	Percentage Difference
British Pound	4,028	2,322	-^2
Coffee	2.945	1.932	-34
Cotton	4.568	2.948	-35
Crude oil	2.732	883	-68
Deutsche mark	4.605	1.904	-59
Eurodollar	1.643	279	-83
Gold	4.110	1.713	-83
Japanese ven	3.838	1.645	-58
U.S. bond	3.005	1.196	-57
Wheat	4.816	2.287	-60
Average	3,629	1,711	-58

mary benefit of expanding the barrier is to reduce the number of days the system is in the market.

Ideally, you should base the width of the barrier on market volatility. A fixed barrier may be too far away to trigger trades within the usual range of daily volatility. For example, the 20-tick barrier is too wide for the Eurodollar market. A volatility-based barrier will respond to market action and provide a more consistent barrier across all markets. The next section discusses the effect of using a volatility-based variable barrier instead of a fixed barrier.

Channel Breakout System with Inside Volatility Barrier

In the previous section we saw the effects of a 20-tick barrier that was outside the 20-day price range. The barrier widened the 20-day price range, and helped to filter out some trades. In the case of the Eurodollar market, the 20-tick barrier was much wider than the normal volatility of that market. Hence, the 20-tick barrier allowed only ten trades to pass through, reducing profits and trading opportunities.

This section will show you how to set up a volatility-based barrier. In an interesting twist, we will set the barrier inside the 20-day price channel (see Figure 5.7). We will have more trading opportunities because the channel will be narrower. The width of the barrier acts as a filter that cuts off trades. You should understand the interaction between volatility and channel width very clearly. If the volatility is low, then the relative channel width will widen. However, if the volatility is high, the actual channel width will be narrower. As volatility increases this system will trade more frequently.

Volatility is defined here as the 10-day SMA of the daily trading range. The daily trading range is simply the difference between today's high and low. Thus, the upper inside barrier is the highest 20-day high minus the volatility. Similarly, the lower inside barrier is the lowest 20-day low plus the volatility. We will go long on the close if it is above the upper inside barrier, and sell on the close if the market closes below the lower inside barrier. The volatility exit is at three times the 10-day SMA of the daily trading range.

Figure 5.8 shows a more detailed view of how the inside barrier works. The actual width of the barrier is narrower, but the width changes every day. The number of trades increases with an inside barrier because the width is narrower than the 20-day channel. Figure 5.8 shows

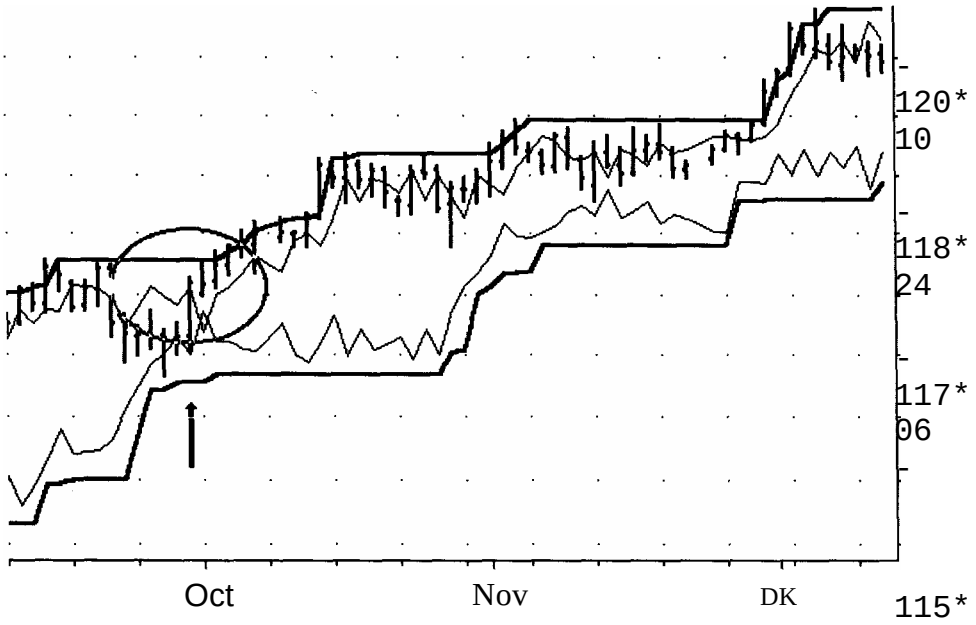

Figure 5.7 The inside volatility barrier superimposed on the 20-day channel shows a long trade in the December 1995 U.S. bond market.

that during narrow consolidations the inside barriers can come close together, or even cross each other. As the inside barriers come close together, the number of trades increases. Thus, the inside barrier system can produce several whipsaw trades in a region of price consolidation.

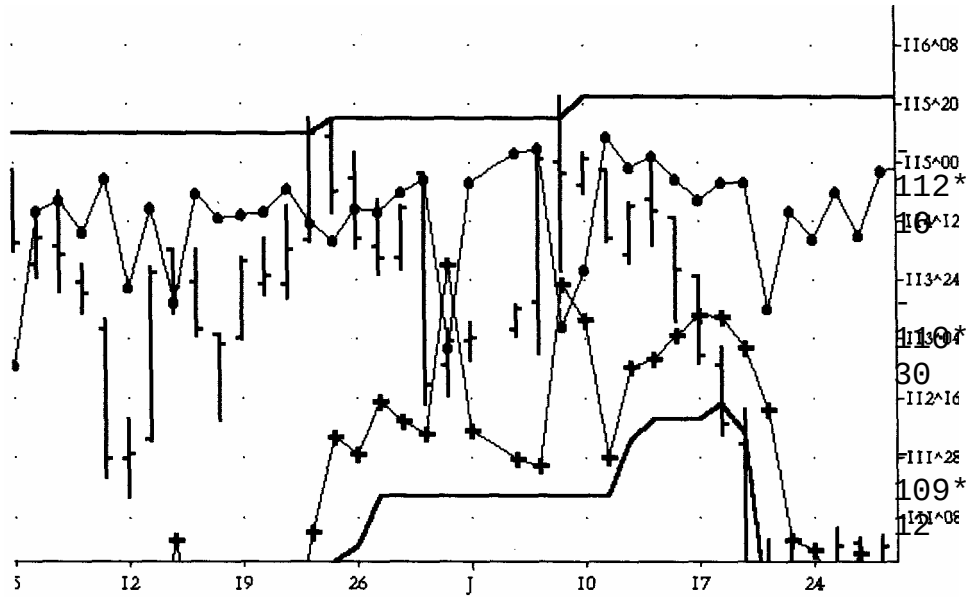

Figure 5.8 The inside volatility barriers come close together during consolidations, increasing trading frequency.

Table 5.7 Results for 20-day channel break out system with inside volatility barrier and volatility exit

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/ Loss Ratio	Average Trade ($)	Maximum Intraday Draw-down	Profit Factor
British pound	49,394	356	37	2.01	139	-27,719	1.20
Coffee	235.77	355	33	2.58	664	-29.451	1.79
Cotton	21.050	281	33	2.31	153	-18.395	1.13
Crude	-	249	32	1.11	-230	-57.720	0.52
Deutsc mark	48.700	318	39	2.12	153	-14.213	1.34
Eurodol	26.975	184	41	2.25	147	-6.600	1.55
Gold	47.900	323	32	2.91	148	-23.620	1.34
Japane yen	63.588	329	35	2.56	148	-19.550	1.36
U.S. bond	28.875	265	34	2.19	109	-22.875	1.15
Wheat	-	279	32	1.73	-63	-30,719	0.81
Total	447,31						
Averag	44,732	294	35	2.18	137	-25,086	1.22

You may dislike the increased frequency in consolidations caused by an inside barrier system. One of the strengths of the usual channel breakout system is that it tends to produce fewer trades during price congestions. Hence, the inside barrier system will not appeal to all traders.

Table 5.7 shows a summary of testing over previous market data. You will notice that the total profits are up 35 percent versus the fixed 20-tick barrier with volatility exit (compare Table 5.4). The total number of trades has more than doubled to 294 over the fixed 20-tick barrier. The higher trading frequency may be attractive to you if your trading costs are low.

Statistical Significance of Channel Breakout Variations

One of the key questions you must ask when you see system variations is whether the differences in the performance are statistically significant. There are many ways to differentiate systems other than comparing

their net profits. For example, one system may produce fewer trades. Another system may produce a smaller drawdown. Some systems may have a higher percentage of profitable trades. A variation may be useful precisely because it suits your trading style.

A paired t-test compares the means of two system variables measured on the same data sets. This test will tell you if the means of the two series being compared are truly different in a statistically significant sense. *You* can find a detailed discussion of the t-test in any book on statistics. For our purpose, the test gives two numbers: a t-statistic for the data and an appropriate reference value (t-critical). If our t-statistic is greater than t-critical, then the difference in performance is statistically significant. The Microsoft Excel 5.0 spreadsheet has a built-in t-test in the Tools menu under Data analysis.

We need a reference or standard system for comparison before we can use the t-test. Here we use a 20-day channel breakout system without any exits as the reference system. If you do not use any specific exits, you have a system in which long entries are short exits and vice versa. Thus, the effects of adding exit strategies should be easy to measure against this reference system. Table 5.8 summarizes the results of testing the 20-day channel breakout system without any exits on the previous data. As usual, there is a $1,500 initial stop and $100 allowance for slippage and commissions.

Let us examine the effects of adding the 5-day high-low trailing stop to the reference system (see Table 5.2). In comparing the net profits from each system, the t-statistic was 2.224 and the t-critical value was 2.262 with 9 degrees of freedom. Thus, the t-statistic was smaller than the reference t-critical value. The average profit for the reference system is $51,368 versus $27,949 with the trailing exit. At the 5-percent level, this difference barely missed being significant. Hence, adding the exit probably significantly reduced average profits. The spreadsheet calculations are given in Table 5.9.

Table 5.10, page 164, compares the number of trades from each system. The average number of trades was 220 with the trailing exit (see Table 5.2), and 118 with the reference system (see Table 5.8). The t-statistic for the number of trades was 8.05. The t-critical value is 2.262, confirming that there is a statistically significant increase in the number of trades. Therefore, the total number of trades increases significantly when we add a trailing exit.

You can now combine the results from these two comparisons. Those results say that adding a trailing exit at the 5-day high-low significantly reduced profits by 30 percent while increasing the number of

163 Table 5.8 Historical results for 20-bar breakout on the close without any exits

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/ Loss Ratio	Average Trade ($)	Maximum Intraday Draw-down ($)	Profit Factor
British pound	92,494	149	30	3.76	621	-29,250	1.58
Coffee	222.04	152	30	5.21	1.461	-26.083	2.34
Cotton	35.870	77	31	1.55	276	-20.270	1.29
Crude	-	130	34	2.91	-165	-27.400	0.70
Deutsc mark	72.000	109	44	2.44	661	-9.975	1.92
Eurodol	25,825	63	44	2.16	410	-10,275	1.73
Gold	29.920	124	35	2.36	241	-39.520	1.30
Japane yen	64.388	121	38	2.61	532	-17.563	1.60
U.S.	-1.956	133	30	2.29	-15	-32.629	0.99
Wheat	-	125	33	1.73	-92	-27,775	0.85
Total	516,38	1183					
Averag	51,638	118	35	2.70	393	-24,074	1.43

Table 5.9 A summary of the t-test comparing the reference system to the CHBOC with 5-day trailing stop

t-Test: Paired Two Sample for Means		
	Reference System	**5-Day Exit**
Mean Variance	51,638 4.85 x10^8	27,948.8 3.77 x10^9
Observations	10	10
Pearson correlation	0.875	
Hypothesized mean	0 9	
tStat	2.224	
P(T<=t) one-tail t Critical	0.027 1.833	
P(T<=t) two-tail t Critical two-tail	0.053 2.262	

Table 5.10 T-test comparing number of trades from reference system and with 5-day exit.

t-Test: Paired Two Sample for Means

	5-Day Exit	Reference System
Mean	220	118.
Variance	1736.72	818.455
Observations	1	1
Pearson correlation	0.410	
Hypothesized mean		
df		
tStat	8.055	
P(T<=t) one-tail	1.05	
t Critical one-tail	1.833	
P(T<=t) two-tail	2.10	
t Critical two-tail	2.262	

trades by 76 percent. Now you have to decide if these changes suit your trading style.

Next we examine the effects of adding the volatility exit to the reference system (see Table 5.3). There is a statistically significant (t-statis-tic: 2.54 > t-critical: 2.26) reduction in average profits from $51,638 to $34,820. Thus, the 33-percent reduction in profits occurs with a significant 61-percent increase in the total number of trades (t-statistic: 8.82 > t-critical: 2.26). Thus, the volatility exit reduces profits and increases trading frequency. Of course, it introduces a neutral zone, and should reduce your overall market exposure. You may like this exit because it responds to a particular exit pattern, such as a large countertrend move. Some traders may prefer the equity curve produced by this exit to the equity curve of the reference system. Others may like the higher trading frequency because it means they will get many opportunities to trade.

The effect of using the 20-tick barrier did not produce a statistically significant reduction in net profits when tested without any exits (see Table 5.5). The average profit per market was $51,638 with the reference system, and $49,989 with the 20-tick barrier. Thus, adding the barrier did not reduce profits significantly. However, it did reduce the number of trades by about 25 percent, which was statistically significant (t-statistic 4.71, t-critical = 2.62), suggesting that the barrier acted as a filter.

The effect of adding a volatility exit to the 20-tick barrier (Table 5.4) also produced no statistically significant difference in net profits.

However, the number of trades was significantly higher. You will have to examine the equity curves to decide if you like the effects of adding the exit.

There was no significant difference in performance between the reference system and the breakout with the inside volatility barrier (Table 5.7). For example, the average profits with the 20-tick barrier are $51,638 versus $44,732 with the inside volatility barrier. However, the number of trades was 60 percent smaller without the inside volatility barrier. The inside volatility barrier produces a statistically significant increase in the trading frequency. Thus, the inside barrier will whet your appetite for frequent trading without a large performance penalty.

The analysis of this section shows that you should use a statistical test to verify that the differences in performance are statistically significant. You can use a spreadsheet for your statistical analysis, or you may use specialized software. You should carefully note how changing exit strategies changed the profits, trading frequency, and drawdowns. Thus, you can easily match an entry signal to your trading needs.

Two ADX Variations

The average directional index is a widely, used measure of trendiness. A test of two small variations of an ADX system showed that the absolute value of the ADX has no particular significance. The test used a $1,500 stop and allowed $100 for slippage and commissions on the following markets: British pound, coffee, cotton, crude oil, deutsche mark, Eurodollar, gold, Japanese yen, U.S. bond, and wheat. All available data from January 1, 1975, through July 10, 1995, were used.

The first system tested entered long or short when the 14-day ADX value crossed over 30. A crossover occurs when yesterday's value is less than 30 and today's value is more than 30 for the ADX. If the 3-day SMA of the close is greater than the 20-day exponential moving average, then the system buys on the next day's open. Conversely, if the 3-day *SMA.* of the close is less than 20-day exponential moving average, then the system sells on the next day's open. The initial stop is at $1,500 and there is a $100 allowance for slippage and commissions. The exit signal was a trailing stop at the highest high or lowest low of the past 20 days.

The second variation does not rely on the absolute value of the ADX; it requires only that the ADX be rising. The ADX was assumed to be rising if it was higher than its value 28 days ago. Otherwise, the rules of the two variations are identical. The results are summarized in Tables

Variations **Table 5.11** Results for ADX >

30 trading system

Market	Profit (S)	Number of Trades	Percentage of Wins	Win/ Loss Ratio	Average Trade (S)	Maximum Intraday Draw-down ($)	Profit Factor
British pound	66,188	51	41	3.72	1,298	-8,869	2.61
Coffee	112.53	64	33	5.76	1.758	-13.065	2.81
Cotton	68.795	50	50	4.09	1.376	-8.355	4.09
Crude	17.780	22	50	2.93	808	-3.550	2.93
Deutsc mark	21.338	57	44	2.00	374	-7.238	1.56
Eurodol	18,675	36	53	2.13	519	-3,350	2.38
Gold	-1.860	50	34	1.85	-37	-25.180	0.95
Japane yen	42.125	47	47	2.56	896	-9.887	2.25
U.S.	2.525	56	34	2.05	-45	-14.588	1.05
Wheat	5,675	48	44	1.65	118	-6,950	1.28
Total	355,63						
Averag	43,745	47	43	2.87	323	-10,103	2.19

5.11 and 5.12. The rising ADX system seems to be more profitable than the ADX > 30 system. A t-test determined that the difference was indeed statistically significant, since t-statistic was 2.76, greater than the t-criti-cal value of 2.26.

These results show that the trend of the ADX is more useful than the absolute value of the ADX. However, using a value such as ADX > 30 is a restrictive condition that reduces the number of trades significantly. *You* will find that the ADX > 30 system is in the market for only 40 to 45 percent of the time spent by the rising ADX system. Therefore, the losses and drawdowns are smaller for the ADX > 30 system. Thus, both approaches have their strengths and weaknesses, and your choice will reflect your trading preferences.

Figure 5.9 and Figure 5.10, page 168, will help you visualize how the two systems work. Figure 5.9 shows the entry due to an ADX rising system in the November 1995 orange juice contract. The ADX indicator along with the reference level of 30 appear in the lower half of the figure. It may appear that the ADX has fumed down, but it is rising on a longer time frame of 28 days. Figure 5.10 shows the entry after ADX has crossed over the 30 level. The entry signal from the ADX>30 system

Table 5.12 Results for ADX rising trading system

Market	Profit ($)	Number of Trades	Percent ^ age of Wins	Win/ Loss Ratio	Average Trade (S)	Maximum Intraday Draw-	Profit Factor
British pound	131,46	180	35	3.43	730	-24,850	1.85
Coffee	217.46	213	28	5.28	1.021	-19.824	2.08
Cotton	57.495	173	35	2.90	332	-17.745	1.54
Crude	-1.590	121	32	2.05	-13	-14.620	0.97
Deutsc mark	74.888	141	49	2.07	531	-10.475	1.99
Eurodol	38,600	96	43	3.45	402	^t.000	2.57
Gold	33.150	182	35	2.46	182	-24.120	1.33
Japane ven	71.850	164	36	2.94	438	-16.763	1.65
U.S.	60.163	164	37	2.52	367	-12.188	1.49
Wheat	5,105	151	52	1.98	15	-24,131	1.04
Total	690,18						
Averag	85,635	159	37	2.91	323	-16,872	1.65

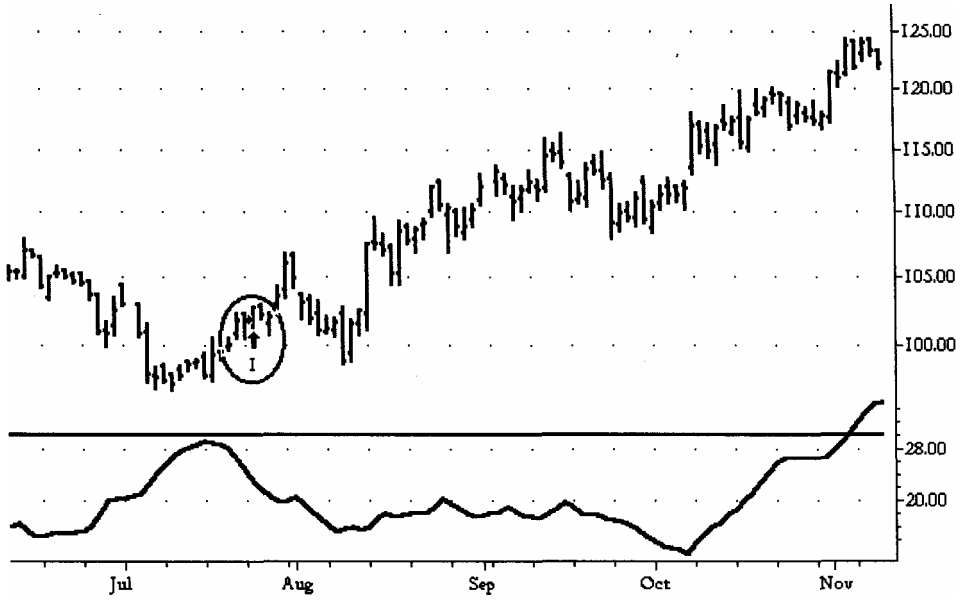

Figure 5.9 The entry point derived from a rising ADX entry system for the November 1995 orange juice contract.

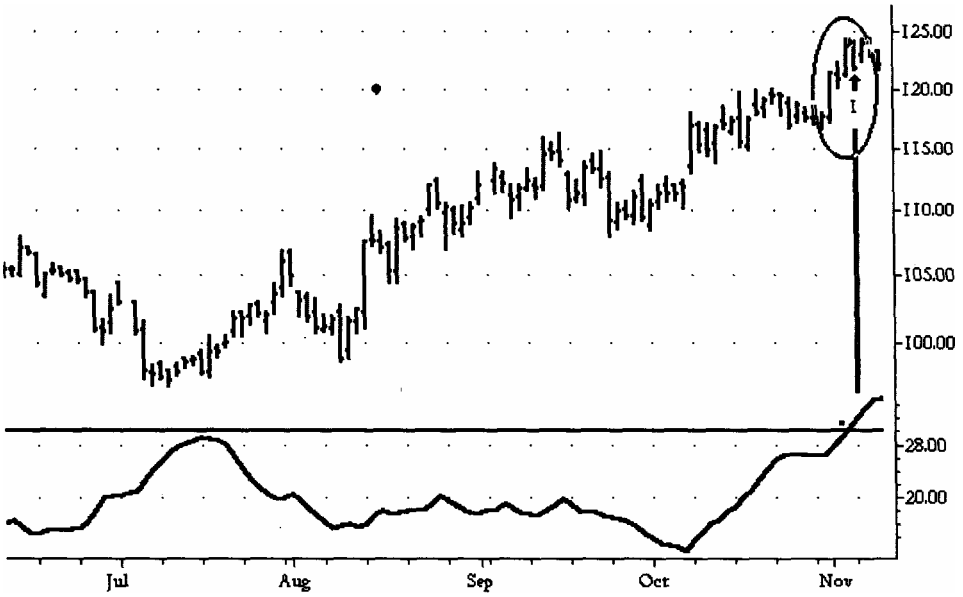

Figure 5.10 Note how the ADX > 30 entry occurs almost 3 months after the rising ADX entry in Figure 5.9.

came 3 months after the signal from the ADX rising system. *You* should expect such delayed entries because the ADX is a heavily smoothed indicator. Clearly, trading styles and preferences will govern which entry method you prefer.

The ADX logic assumes you are trying to confirm the presence of a strong trend. These entries could occur after prices have made a small move, since the heavily smoothed ADX takes several days to react to changing prices. Many traders do not like to buy on strength or sell on weakness. These traders prefer to lower risk at entry by buying a pull-back or selling a small bounce in prices. In the next section we review a variation that tries to trade the "pullback" in prices.

The Pullback System

An old market maxim says, "Buy on a pullback into support." Many traders like to trade the pullback because it often provides an entry point with relatively low risk. Contrast this philosophy with trading the ADX systems, which buy on strength or sell on weakness. The pullback maxim, however, is not a precise statement of a trading system. We have to define what we mean by pullback and what represents support. This system is a variation of the CB-PB system examined in chapter 4. Here the

pullback is defined relative to a moving average rather than after a 20-day breakout.

A pullback is simply a minor correction within an uptrend. The pullback itself could take many forms. For example, you can define pull-back as thrte consecutive down days. Perhaps you can define pullback as a "return to support" by a moving average. *You* can pick a variety of averages, such as a 20-day or 50-day simple or exponential moving average. The term "return to support" is vague—you must decide if prices must touch the average, go below the average, or get within 1 percent of the average. Once you agree what "pullback" and "support" mean, you must then decide at what point to place your buy order. For example, you could buy at the next day's open, the next day's high, or at the 5-day high. Picking a precise definition will allow you to build many variations of this system.

We want to build a system that recognizes a retracement in both downtrends and uptrends. We will define a pullback as a new 5-day low in an uptrend or a new 5-day high in a downtrend.

Next, we must define the trend. We will assume that if the trend is up, the low remains above the *d-day* SMA when the market makes a new 5-day low. Similarly, the high will remain below the *d-day* average when the market makes a new 5-day high. We arbitrarily pick a 50-day SMA as the reference moving average because the prices will stay above or below this average during strong trends. Thus, the trend is defined as up when the market makes a new 5-day low but the low remains above the 50-day SMA (see Figure 5.11). The matching condition for the downtrend is that the new 5-day high remains below the 50-day SMA.

You can imagine other variations of this system. For example, you can add a trend filter, using the ADX as suggested by Connors and Raschke (see bibliography for reference). They suggest using a 14-day ADX value greater than 30 and using a 20-day exponential moving average. Another option is to use a 14-day RSI or stochastic oscillator and to look for reversals. For example, you could look for the stochastic to fall below 20 and then rise above 20 to define the buying point.

The results of tests of the pullback systems using the same data sets as for all other systems in this chapter are shown in Table 5.13, page 171. We again used a $1,500 initial stop and allowed $100 for slippage and commissions. The entry was on the open after a new 5-day low above the 50-day SMA and vice versa. The exit was on the trailing 20-day high or low. The basic idea of the pullback system seems valid when you consider its profitability over a wide range of markets. The 20-year test period also confirms that the pullback system will find profitable trades in the future.

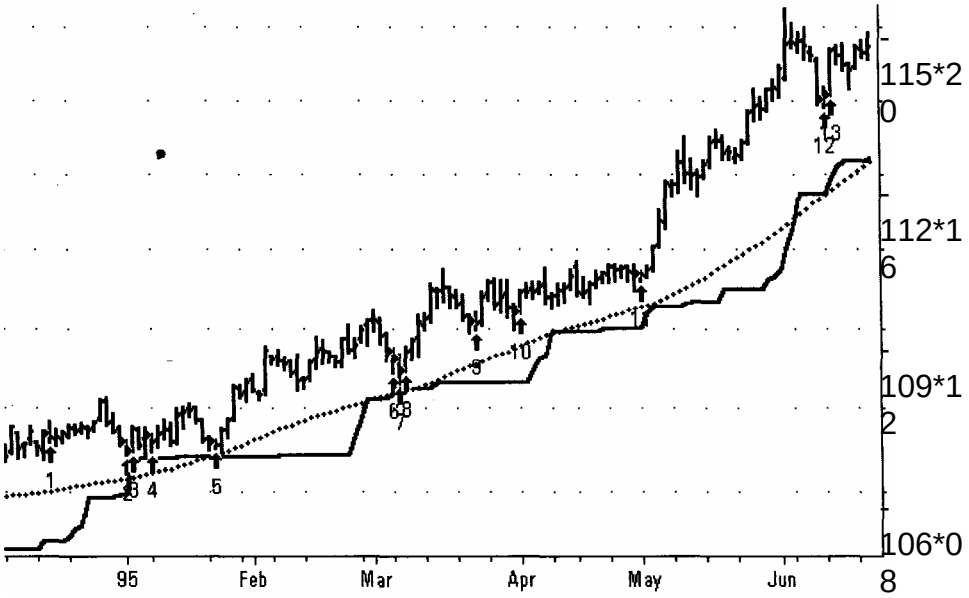

Figure 5.11 The pullback system had many entry points into the strong uptrend in the June 1995 U.S. bond market. The solid line is the trailing 20-day low. The 50-day SMA is shown by crosses.

The percentage of profitable trades is relatively low, about 20 to 30 percent. However, the low win ratio is offset by the high average win-loss ratio. The drawdowns are moderate compared to other systems we have studied. The pullback system seems to work best in markets that have regular corrections within choppy trends. The pullback system also likes markets that make swing moves. Note, for example, the small loss in crude oil and the small profit in the U.S. bond market. The other trend-following systems discussed in this book have tested poorly on these markets, which often have choppy trends.

In keeping with its design philosophy, the maximum drawdown figure is substantially smaller than in other trend-following systems. However, the results in Table 5.13 are not as attractive as some of the trend-following systems we have seen. The reason is obvious in the live hogs chart shown in Figure 5.12. The market did not make profitable swing moves after retreating to the 50-day average. Your exit strategy is more important in such markets that bounce weakly off the 50-day average. You can experiment with your favorite exits, or use discretion.

So far we have not taken advantage of a key design feature. Since we are buying or selling after a pullback, we hope to get a low-risk entry point. A low-risk entry point is ideal for using a variable-contract

Table 5.13 Results for pullback system: new 5 day low above 50-day SMA or new 5<lay high below 50-day SMA; exit on trailing 20-day high or low; $1,500 initial stop, $100 S&cC

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/ Loss Ratio	Average Trade ($)	Maximum Intraday Draw-down ($)	Profit Factor
British pound	122,26	149	28	5.62	821	-16,569	2.21
Coffee	205.03	174	21	9.34	1178	-26.063	2.52
Cotton	46.630	132	30	3.96	353	-10.360	1.72
Crude	1.840	90	32	2.21	20	-12.070	1.05
Deutsc mark	30.725	129	34	2.82	238	-14.963	1.46
Eurodol	16,575	82	29	4.01	302	-4,200	1.66
Gold	34.320	139	27	4.04	247	-25.430	1.47
Japane ven	27.575	135	31	3.03	204	-14.925	1.37
U.S.	35.850	129	31	3.84	278	-15.400	1.43
Wheat	-7,588	134	24	2.70	-56	-21,131	0.85
Total	513,23						
Averag	57,869	129	29	4.16	359	-16,111	1.65

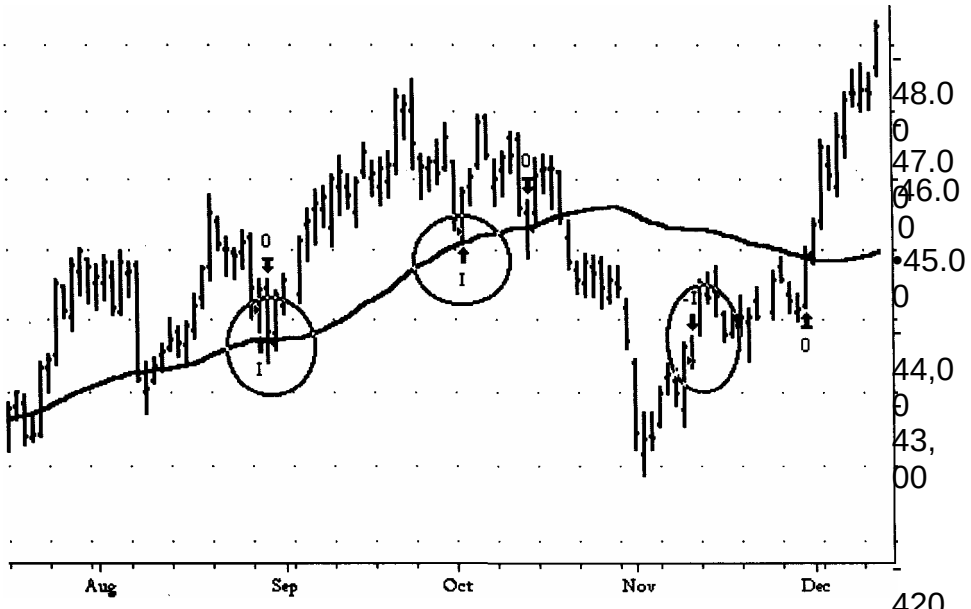

Figure 5.12 The choppy trend in live hogs triggered the system entries but did not generate significant profits. This is a common problem in choppy markets, and your exit strategy becomes even more important.

money-management strategy. If you can risk $10,000 per position signaled by the pullback system, then trade up to a maximum of ten contracts using the 5-day high-low range as the measure of volatility. In Table 5.14, we traded a new 5-day high or low beyond the 50-day average. The exit was placed at the 20-day trailing high or low, and we used a $1,500 initial stop, and charged $100 for slippage and commissions.

There is a striking difference in performance among a one-contract strategy and a variable-contract strategy with a ten-contract limit. The profits of the latter strategy were more than six times greater. However, the drawdown increased almost eight times on average, so the gains come at a price. Note that the drawdowns are still smaller than always trading ten contracts. Thus, the variable-contracts strategy could be better than trading the equivalent number of fixed contracts. *You* can test other variable-contract approaches with this entry strategy to match your preferences.

In summary, the basic idea behind the pullback system is valid. It has relatively high win-loss ratio and average trade. *YOVL* could try to

Table 5.14 Results for pullback system with a maximum of ten contracts

Market	Profit ($)	Number of Trades	Percentage of Wins	Win/Loss Ratio	Average Trade ($)	Maximum Intraday Drawdown ($)	Profit Factor
British pound	871,71	126	32	5.89	6,919	-67,419	2.74
Coffee	794.99	155	24	6.68	5.039	-	2.11
Cotton	406.25	134	28	4.63	3.031	-	1.83
Crude	33.360	91	24	3.54	367	-68.100	1.13
Deutsc mark	297.97	135	29	3.79	2.207	-	1.54
Eurodol	237,85	68	38	3.79	3,498	-35,750	2.34
Gold	129.29	135	24	3.99	958	-	1.24
Japane ven	86.288	128	26	3.26	674	-1	1.10
U.S.	316.05	140	22	4.82	2.258	-	1.65
Wheat	19,419	126	23	3.22	154	-	1.06
Total Averag	3,193, 352,64	122	27	4.36	2,511	-	1.74

add filters to improve system performance. You should consider a variable-contracts money-management approach to exploit the low-risk entry points.

The Long Bomb — A Pattern-based System

Many a football team has lived, and died, by the "long bomb." In American football, this is a pass play designed to gain big yardage by going deep down the playing field. A successful long bomb can rekindle enthusiasm in your team, demoralize the opposition, and even get a quick score when little time remains. It is a gutsy play, but not without some risk. This section discusses a pattern-based system inspired by the philosophy of the long bomb. Pattern-based systems allow you to react immediately. However, the patterns do not repeat frequently, and the market does not have to follow through on the pattern each time. *You* must also be careful when you test the pattern to use a sufficiently large data set.

The long bomb is a 5-bar, bottom-picking pattern. It is related to market action near double bottoms. The usual sequence is that a market probes for a bottom. As big players sense a bottom, they buy in "bulk" and produce a sharp rally. Other traders feel this may be an opportunity to short, and the smart-money-led rally is thwarted by short-sellers late to the party. As a result, the market retests the prior bottom. If there is no significant selling on the retest, the market is ready to resume an upward move, and does so with a strong surge. The strategy here is to get in during the upsurge—a simple enough idea. As it bursts out of the base, the market closes above the highs made over the past few days. If the following conditions are satisfied, buy tomorrow just above today's high:

1. Today's close is greater than the high of 2 days ago
2. Yesterday's close is greater than the high of 3 days ago
3. The close 2 days ago is greater than the high of 4 days ago

This relationship is perfectly general with no market-specific assumptions. In addition, there is no need to optimize the system. The following twist makes this system interesting. Suppose you buy multiple contracts, betting $10,000 per trade. *You* can use the difference between today's close and the 5-day low, convert this "range" into dollars, and

calculate the number of contracts. Thus, if the "range" is $2,000, you will buy five contracts and use a $10,000 hard-stop on the position. Here is another twist. You will exit at the trailing 50-day low to get a long-term system.

By now you should understand why the name of the system is the long bomb. By buying multiple contracts and using a very slow exit, we are following the TOPS COLA strategy, and, in football parlance, going deep.

The Power Editor code for Omega Research's Trade Station™ software is:

```
input : dx (50) ;
Vars: Numc(O);
if C - lowestClow.5) 0 0 then Num C = intportion(10000/((C-
1owest(1ow.5))*Big
   Pointvalue)) else NumC = 1;
Condltloni - c > h[2] ;
Condition? - c[l] > h[3];
Conditions = c[2] > h[4];
          If Condltioni and Condition2 and conditions then buy
("12S Signal") NumC contracts at high + 1 point
stop;
ExitLong at Lowest(1ow,dx)[l] - 1 point stop;
```

An input, *dx,* which is the number of days in the exit, allows us to experiment with the exit strategy. Just before we calculate the number of contracts, we should double check that today's close is above the 5-day low to avoid division by zero. The three conditions specifying the pattern are entered as inequalities. If the entry conditions are satisfied today, we will enter tomorrow just above today's high on a buy stop. Hence, we could see some slippage if the market opens beyond our stop, but this barrier entry condition acts as a filter and reduces the number of trades.

Figure 5.13 shows how this entry condition looks on a real bar chart, using the March 1995 Eurodollar contract just after a significant market low. The long-bomb pattern went long just after the retest of the low, after the first bounce. Notice that there was no retracement after entry: like the long bomb, it was up, up, and away. A similar pattern is shown in Figure 5.14 for the December 1995 heating oil contract.

Strange as it may seem, you will find that the long-bomb pattern occurs frequently at market bottoms. Table 5.15, page 176, gives the results of long-term testing over 10 markets. The period chosen is

from January

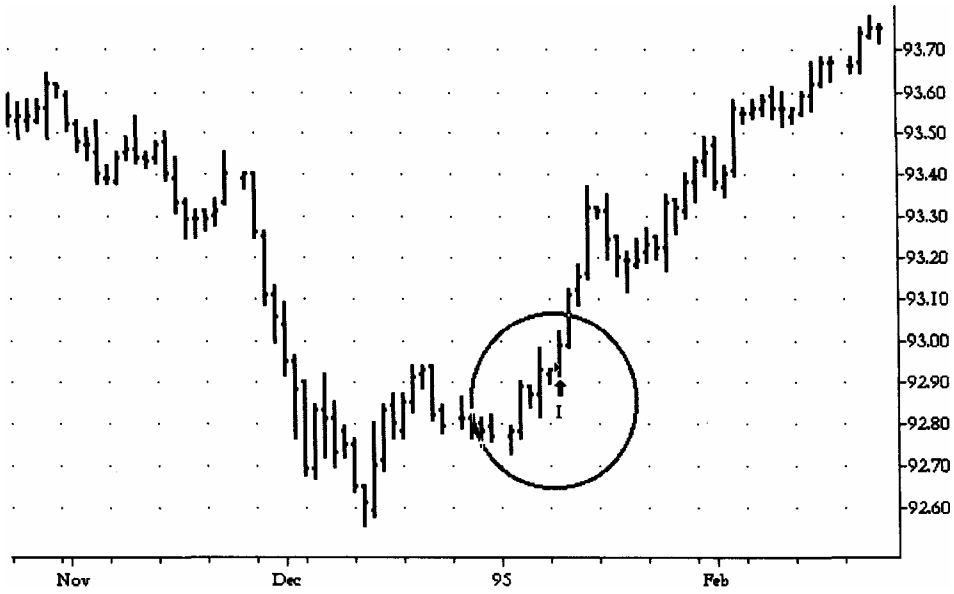

Figure 5.13 The long-bomb pattern enters as the Eurodollar accelerates out of its major bottom.

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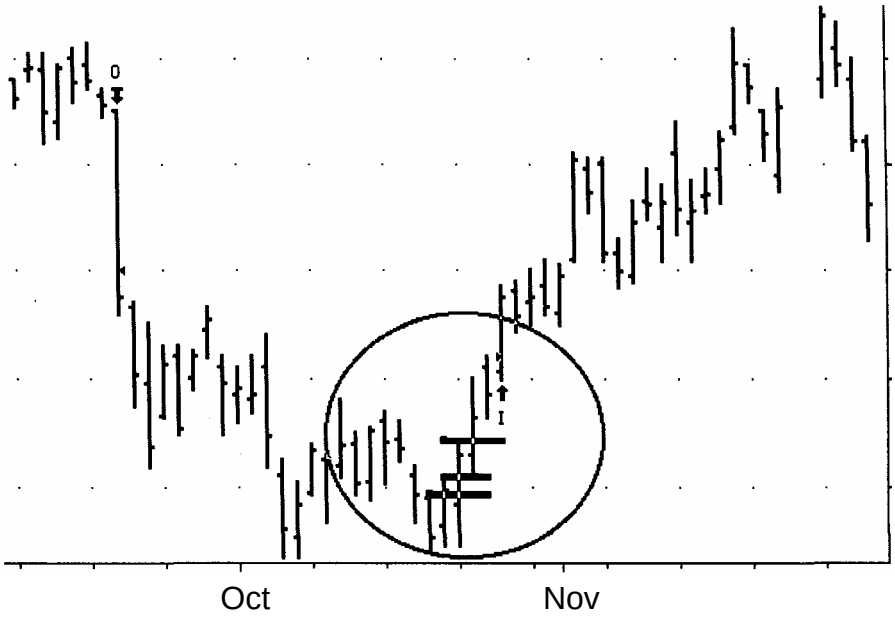


Figure 5.14 The long-bomb pattern in the December 1995 heating oil contract. The entry point saw good followthrough with little retracement.

Long-term results for long-bomb trading system

Market	Profit ($)	Profit Factor (Gross	Number Wins; Trades; Percenta	Maximu Number of Contrac	Maximum Intraday Drawdown
British	114,313	1.54	12;35;34	9	-96,407
Coffee	417.770	3.03	9:34:26	5	-49.660
Cotton	222.590	1.98	10:31:32	25	-136.040
Deutsche	234.263	2.17	10:31:32	22	-60.725
Eurodollar	142.825	1.76	12:29:41	57	-72.200
Heating oil	25.544	1.07	12:45:27	22	-135.565
Japanese	779.324	5.93	11:24:46	17	-38.000
Soybeans	62.018	1.20	11:42:26	28	-120.695
Swiss franc	256.453	2.70	10:26:38	15	-42.310
U.S. bond	272,363	2.41	12;33;36	9	-63,400

1, 1982, through July 10. 1995, a 14-year period that spans a variety of market conditions. The results would be even better if we included a longer test period. We used a $1,500 stop, allowed $100 for slippage and commissions, and exited at the trailing 50-day low. We also calculated multiple contracts for a $10,000 investment, as explained above.

Table 5.15 does not show the fact that the average win/loss ratio was well above 3 for most of the markets. The results show that this system was profitable with multiple contracts, with considerable potential for drawdown. You can test a variety of exit strategies with this entry. You could also derive and test other patterns, such as a 3-bar pattern or 20-bar pattern.

Note here that we have around 30 trades in each market. If we assume that all markets are equivalent, we have 330 trades in Table 5.15, giving us reasonable confidence about system performance. Observe that these 330 trades occurred over a period of 14 years, averaging 24 trades a year, perhaps two a month. This may be a relatively low frequency for most trading programs. Hence, you should strive to develop a large portfolio of patterns, so that you will generate perhaps ten or more trades a month.

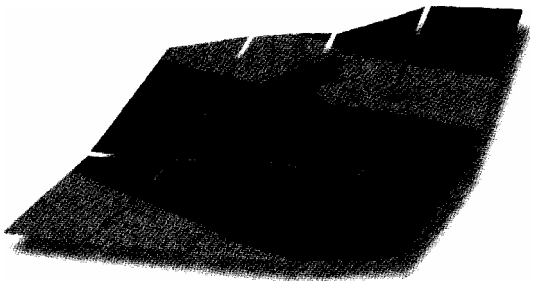
Testing patterns can be interesting, but must be done carefully. For example, there are a large number of candlestick patterns with tantalizing names and exciting descriptions. However, they often do not withstand thorough testing. The long-bomb pattern shows that you do not need complexity to achieve your means—just a particular market intuition.

Summary

In this chapter we saw how you can develop variations on a theme. We saw how the profit, trading frequency, and drawdown change with different exit strategies using the channel breakout system. Once you find a variation you like, you can use statistical tests to verify that the changes in performance are significant. We explored two variations on the ADX idea. The tests showed that the trend in the ADX is more useful than a fixed value, such as 30, in designing trading systems. We then saw a variation of the CB-PB system for long and short trades. In this case the pullback was referenced to a moving average rather than to the 20-bar channel. Lastly, we looked at a bottom pattern that is a variation of the usual double bottom formation. That example illustrates how you can take widely recognized patterns to form your own variations.

In this chapter we explored how you can easily develop variations of well-known ideas. Once you know that the results are statistically significant, you can evaluate how well they fit your trading style. In this way you can develop a large collection of systems for trading.

Chapter



Equity Curve Analysis

The holy grail of trading system design is the perfectly smooth equity curve.

Introduction

Only the equity curve provides a complete and continuous picture of your system's performance over time. The usual test summary tells you little about how your design trade-offs alter performance on a day-to-day basis. Hence your system development is not complete until you understand the impact of your decisions on the evolution of account equity.

In this chapter we take a detailed look at how to measure the smoothness of the equity curve using the standard error (SE) from linear regression analysis—the larger the SE, the rougher the equity curve. Then we see how the equity curve for the 65sma-3cc system changes with different exit strategies at the contract level. You will get a feel for how your design choices translate into equity changes.

Next, we discover how SE changes when you combine two systems trading the same market. A common belief is that trading many different markets gives a smoother equity curve. We explore this belief by combining two markets that have some positive covariance.

We then explore the monthly changes in equity curves, examining the performance of the 65sma-3cc system trading the deutsche mark over monthly intervals of different lengths. These quantities are termed the interval equity changes. Our goal here is to see how a system does

over all 1-month, 3-month or 6-month intervals in the test period. These measures help in understanding the effects of adding a trailing stop or changing exit strategies.

These tests show that exit strategies alone do not improve equity curve smoothness (that is, reduce standard error); we look at changing a system's design. Filtering the usual channel breakout system gives a smoother equity curve.

The usual performance summary reveals none of this information, so the new insights from this analysis make it well worth the effort. After reading this chapter you can:

1. Measure the smoothness of an equity curve.
2. Understand the impact of system design on changes in the equity curve.
3. Grasp the effect of diversification on equity curves.
4. Recognize the benefits of using filters in system design.

Measuring the "Smoothness" of the Equity Curve

This section shows how to use linear regression analysis to measure the smoothness of an equity curve. We will use contrived data to perform actual calculations. You will understand how to use standard error and how to calculate the risk reward ratio. In later sections of this chapter we apply these ideas to market data and trading system calculations. The main advantage of using linear regression analysis is that it provides a consistent framework to analyze every equity curve.

The equity curve of your trading account or system is simply its daily equity. The daily equity is the sum of your starting account balance, plus the profit or loss of all closed trades, plus the profit or loss of all open trades. Ideally, we want an equity curve that rises steadily in time, as shown for the hypothetical data in Figure 6.1. The slope of this equity line is $100 per day, all the points lie exactly on a straight line through zero, and the standard error is zero. This line shows an account whose equity increases exactly $100 each day.

Since we all have some trades that lose money, the equity curve is never a perfectly straight line. As you begin to compare the equity curves of different trading systems, you need a way to measure their

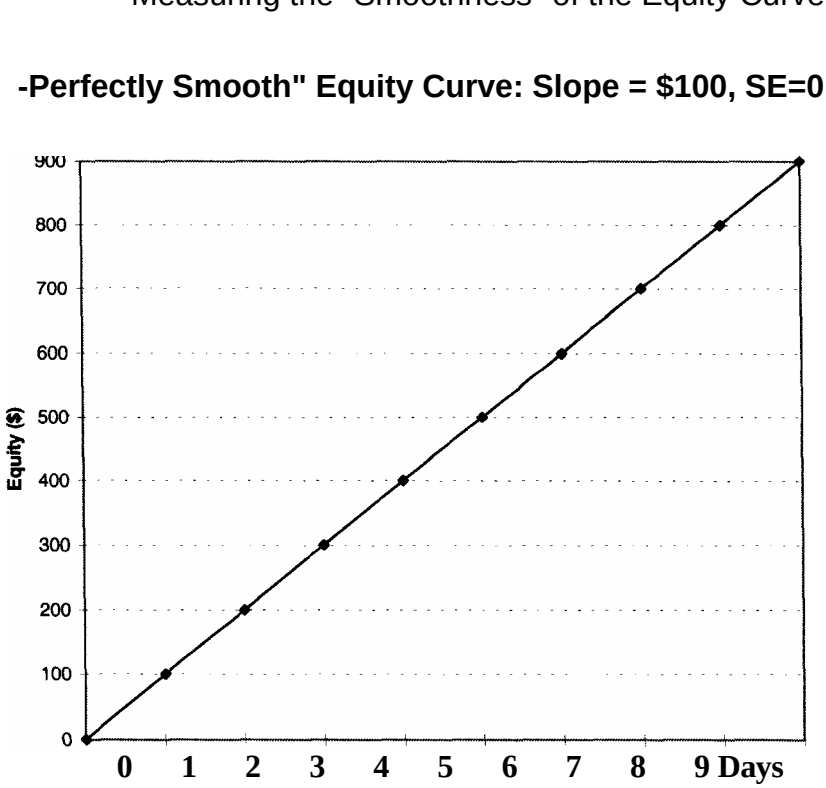


Figure 6.1 The perfectly smooth equity curve.

"smoothness." If you compare two systems with similar performance, the one with the smoother equity curve is preferred. We assume here that you are comparing system performance over the same time unit (days) and similar length (months or years). *You.* could compare systems over other time units and length, but you must recognize that sometimes you may not be comparing these systems on a consistent basis.

We will use linear regression analysis to determine smoothness. One of the outputs of linear regression analysis is the residual sum squares (RSS). RSS is the sum of the squared vertical distance between the actual data and the fitted regression line at each point. The next step is to divide the BSS by the number of data points minus two, and then to take the square root, to calculate the standard error. The standard error measures the smoothness. If all the points fall exactly on the best fit linear regression line, then RSS is automatically zero, and the standard error is also zero, for the ultimate smoothness in an equity curve.

The curve in Figure 6.2 shows more hypothetical data. The slope of the best-fit linear regression line through zero is again $100. However, the points are scattered on either side of the best fit line. The standard error for these data is $82. If you measured the vertical distance between the actual equity value and the best fit line every day, on average, this absolute, average vertical distance is $82. Thus, the standard error tells you typically how far a point is from the best-fit line.

In Figure 6.3, which uses even more hypothetical data, the slope of the best-fit equity curve is still $100, but there is a lot more scatter in the data on either side of the best-fit line. As expected, the SE is almost four times bigger, at $318.

You can get a better feel for what standard error means by looking at Figure 6.4, page 184, which contains the data in Figure 6.3 plus two lines one standard error away from the best-fit line. The data points are

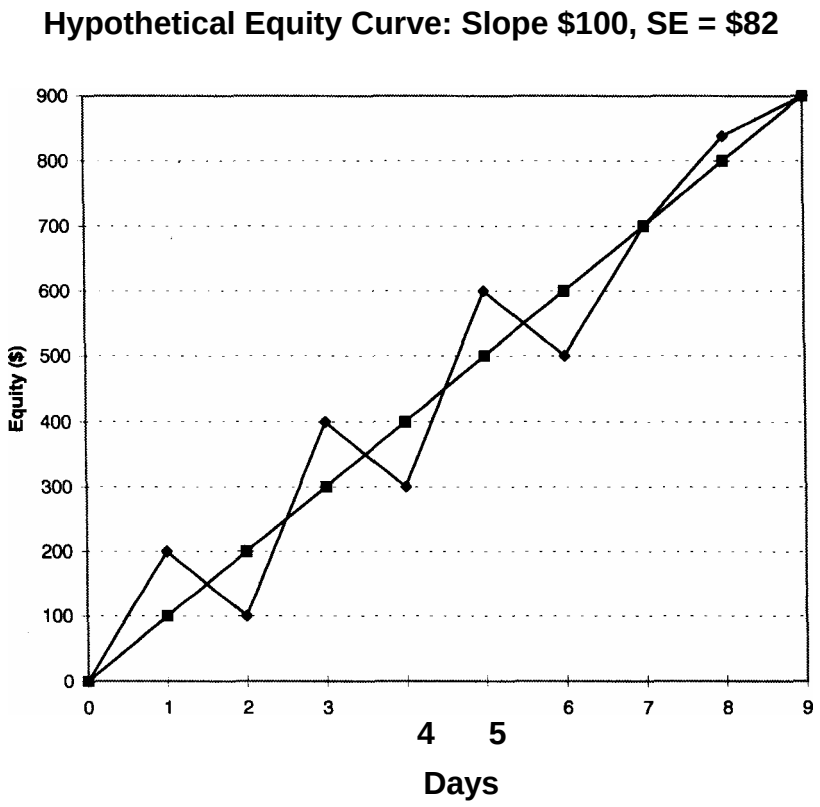


Figure 6.2 These hypothetical data have a slope of $100, and the scatter about the regression line increases the standard error to $82.

Hypothetical Equity Curve: Slope= $100, SE = $318

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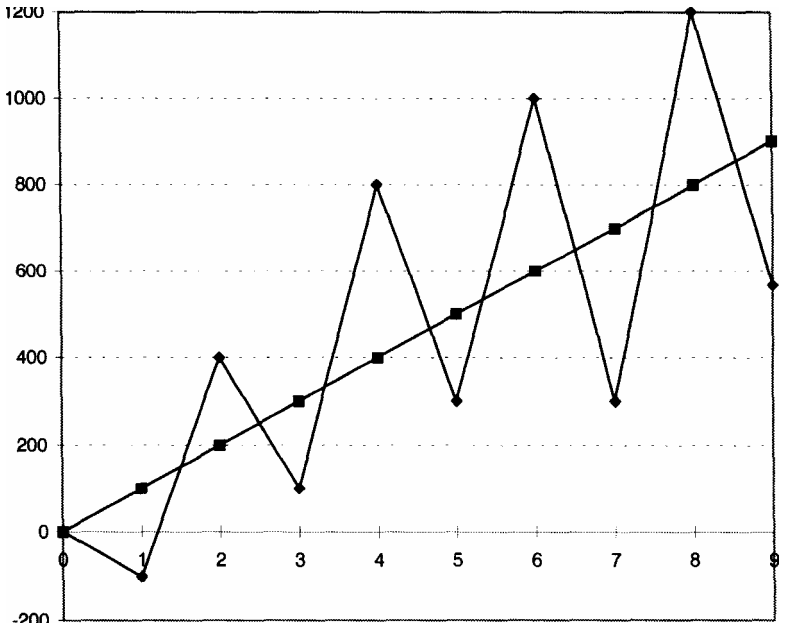

Figure 6.3 These data have a $100 slope, but the large scatter about the linear regression line increases the standard error to $318.

inside, or close to, the standard error lines. Remember we find the standard error by squaring the vertical distance between the actual point and the best-fit line, summing this up, and dividing by the number of points less two. Hence, the standard error is the average "offset" on either side of the best-fit line, and the data clearly lie inside or close to the "offset" or standard error.

Thus, the standard error from linear regression analysis is a good measure of the smoothness of the equity curve. Note that the linear regression method can be applied to any number of time periods and to any equity curve. The standard error offers a general, consistent, and powerful method to measure smoothness.

The combined SE of two or more equity curves will be smaller than the SE of the individual curves only if the curves are negatively correlated. Negative correlation means that when one increases, the other decreases. For a data set that is exactly negatively correlated to the data

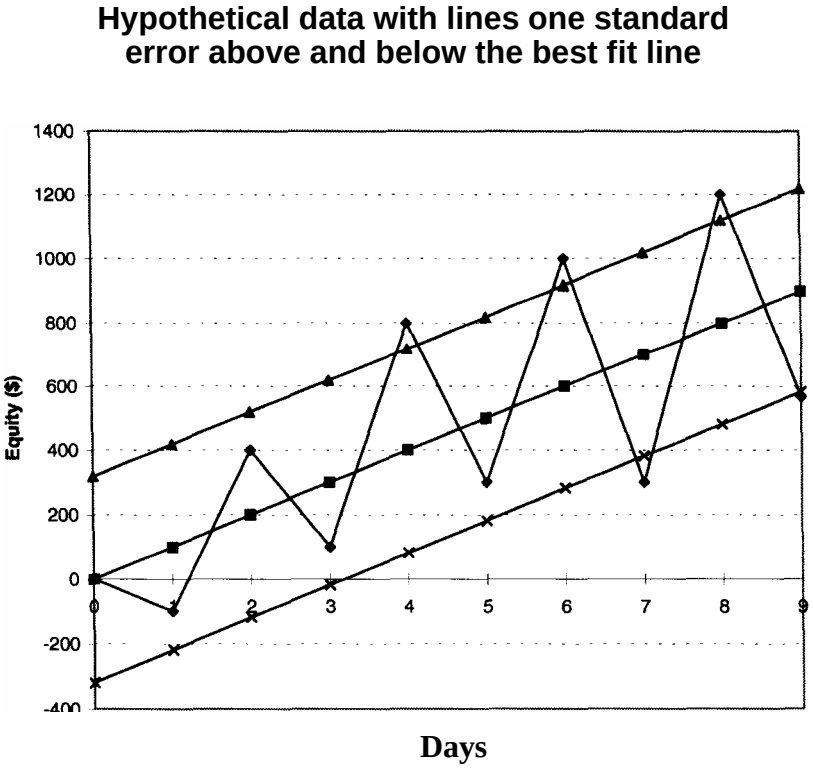

Figure 6.4 The same data as in Figure 6.3 with lines on either side of the best-fit line one standard error away.

in Figure 6.3, the combined equity curve is a perfect straight line with zero standard error (see Figure 6.5).

Lowering SE is one of the arguments for diversification, usually interpreted as trading many markets within a single portfolio. If the markets are negatively correlated at least some of the time, then the joint equity curve of the combined portfolio will be smoother. Note that the slope of the joint equity curve will be just the algebraic sum of the slopes of the individual equity curves. This simply means that the slope of the line through the origin will change to accommodate all profits made over a given period.

You can expand the diversification theme to include different systems on the same market. Again, the equity curve will be smoother only if the systems are negatively correlated. If the systems have positive co-variance, then the overall standard error will increase. Of course, if all systems are profitable then the slope will increase as well. Remember that slope and roughness are independent. Thus, increasing the slope does not translate into a smoother equity curve.

Hypothetical equity curves with perfect negative correlation

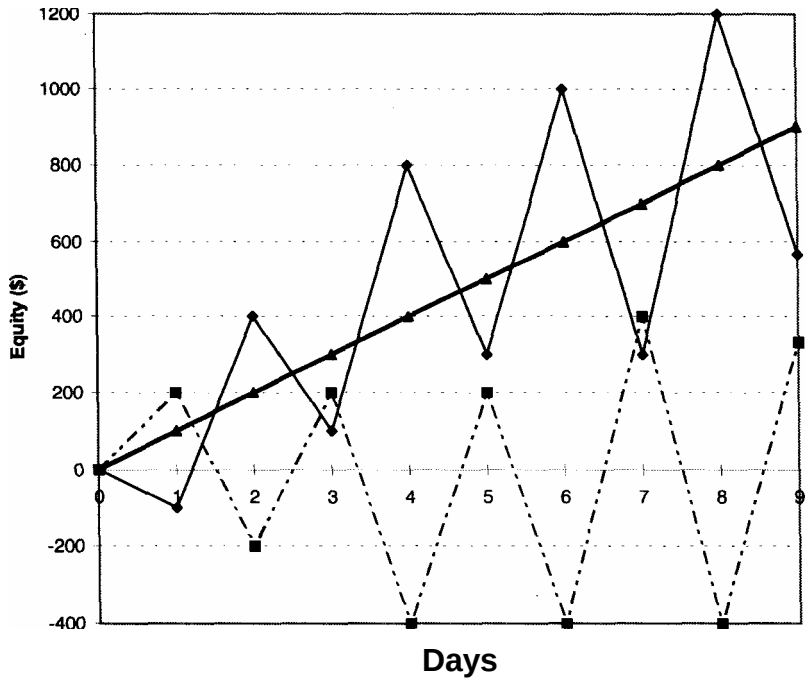

Figure 6.5 Hypothetical equity curves that are perfectly negatively correlated;
combining them reduces the SE to zero in this contrived example, because the resultant equity curve is a perfect straight line.

We can extend the linear regression-based analysis to calculate the risk-reward ratio of a particular system by taking the ratio of the slope to the standard error. This is a quick and reliable way to compare different systems tested over the same data sets. This calculation assumes we are using daily data and looking at system paper profits.

RRR (risk reward ratio) = slope / standard error.

In the three hypothetical cases, the RRR approaches infinity for the first system because its SE is equal to zero. For the second system it would be 1.21 (100/82) and for the third 0.31 (100/318). There is little doubt we would all prefer the first system if one ever existed. You can use a spreadsheet such as Microsoft Excel for linear regression calculations. For example, in Excel you can use the built-in tools to find all relevant regression data by just filling out a template (pick Tools, then Data Analysis, then Regression, and fill out the template). Otherwise,

you could use one of the many easily available packages for statistical analysis.

In the following sections we use SE to measure equity curve smoothness. Remember that increasing the slope does not automatically increase smoothness (that is, reduce SE). We will examine how different system designs affect portfolio level equity curves.

Effect of Exits and Portfolio Strategies on Equity Curves

All the decisions you make about entries, exits, and stops show up in the slope and smoothness of the equity curve. In this section we will explore the equity curves of the 65sma-3cc model using a deutsche mark actual contract with rollovers. We will study how the equity curve responds to changes in system design. Our yardstick for comparison will be the standard error calculations described in the previous section. We will not test continuous contracts, because the actual contracts with rollovers provide a better simulation. Besides, the System Writer Plus™ software from Omega Research can be used here to develop detailed equity curves.

The test set includes actual deutsche mark contracts from March 1988 through September 1995. We allowed $100 for slippage and commissions, and the software automatically rolled over the contracts on the 20th day of the month preceding expiration.

The procedure is as follows: the daily equity of the test case is exported into an ASCII file, which is then imported into the Microsoft Excel 5.0 spreadsheet. The regression calculations are perfomed in Excel using their built-in tools for regression analysis, as explained in the previous section.

We first tested the 65sma-3cc model on the deutsche mark contracts without any stops or exits (case 1). The case 1 equity curve (Figure 6.6), has a linear regression slope of $17.54, and a standard error of $4,043. During the test period, the 65sma-3cc model produced paper profits of $24,288, with a profit factor of 1.34 and a maximum intraday drawdown of-$11,938, trading one contract at time. The equity curve for case 1 is rather jagged, with a significant retracement in 1992, and is typical of trend-following systems without any exits. Note how many trades gave up significant profits before being closed. Also, if the market enters an extended sideways period, this model will suffer drawdowns, and you can go a long time before new equity highs.

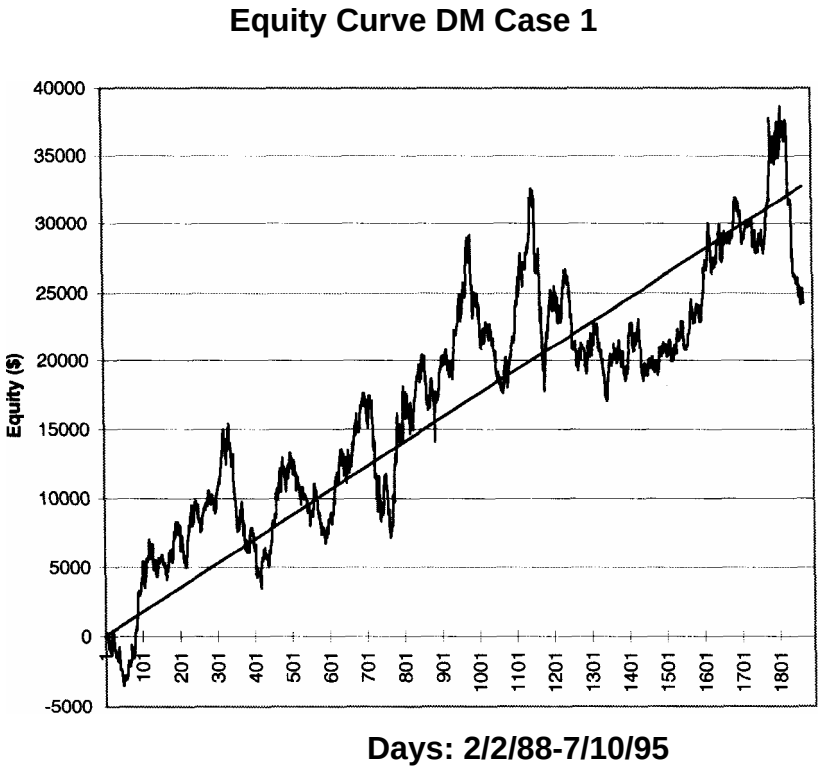

Figure 6.6 Case 1, the 65sma-3cc model without any stops or exits, on actual deutsche mark data with rollovers.

Cae 2 is the same system with a $1,500 hard stop. The equity curve (Figure 6.7) shows that adding this stop decreased profits and reduced smoothness compared to case 1. The net paper profit dropped sharply from $24,288 to just $6,913, for a meager profit factor of 1.10. The maximum intraday drawdown almost doubled, to -$20,225, suggesting that a $1,500 stop is too tight. The equity curve (see Figure 6.7) shows the lower profit and higher drawdown. Note that the slope has halved from case 1, to $8.24, and the standard error has increased to $7,517. Hence, when you set your stop, compare the hard dollar amount to the market's volatility, and ensure you are safely outside its zone of random movements. Many traders seem to favor tight or close stops, and these calculations suggest that tight stops may degrade long term performance.

In case 3, the stop was increased to $5,000. This produced the same results as case 1. Thus, at $5,000 the initial stop was so wide that it produced results identical to testing without any stops. Thus, returning to

Figure 6.7 Case 2, the deutsche mark contracts and 65sma-3cc system with $1,500 initial stop.

the volatility argument, you should check that your stop is not so wide that it is virtually the same as not using a stop at all. Of course, a wide stop will act as firewall of last resort, and is useful for the occasional hiccup in the markets.

Many traders agree that exit strategies play a crucial role in a system's ultimate success. A common practice is to use several exits for a single entry signal. The 65sma-3cc system was tested with two exits, one an exit at the lowest low or highest high of 10 days, and the

other the volatility-based exit discussed in chapter 5.

The result of using both these exits (case 4) with a $5,000 initial stop was to reduce the paper profits even further, to $3,737, for a paltry profit factor of 1.07. The maximum intraday drawdown of-$13,337 was actually larger than the calculations with no stops at all. You would expect the equity curve to be smoother as a result of the exits. As Figure 6.8 shows, the slope decreased to $5.08 and the SE was $3,368. The new slope was only 29 percent of the slope without stops, but standard error

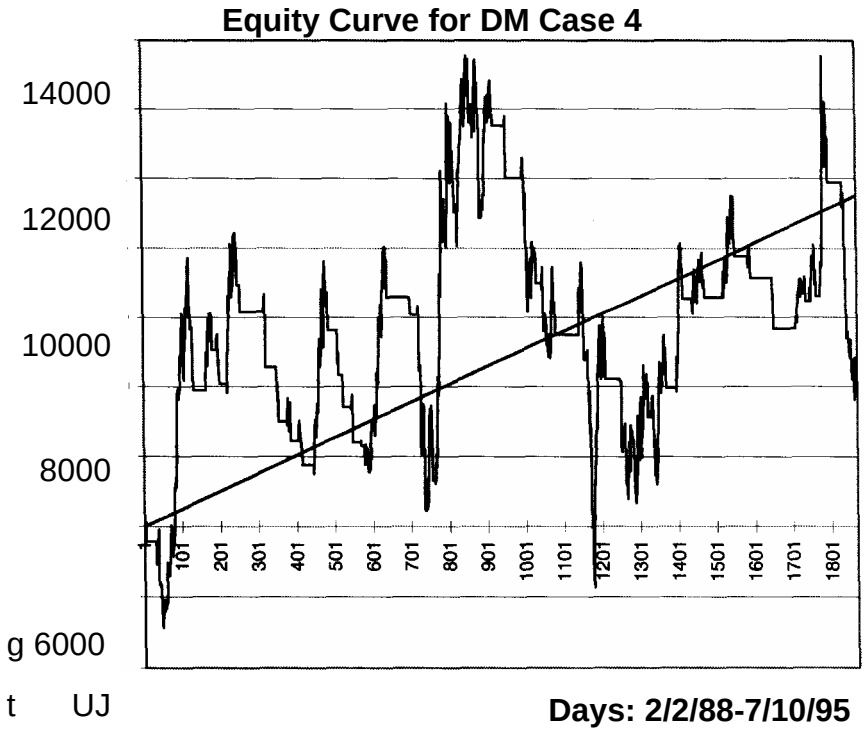

Figure 6.8 The 65sma-3cc system on DM with trailing stop, volatility stop, and $5,000 exit.

was only 17 percent smaller. Thus, there was a sevenfold drop (85 percent reduction) in reward for only a 17 percent reduction in risk—too high a price to pay for this system.

Notice how the equity curve for case 4 looks qualitatively different from that for case 1, because it has "flat" portions where the exits take the system out of the market. Case 4 neatly illustrates one of the tradeoffs in system design: you can go for higher profits or a smoother equity curve. Your choice may depend on many factors, including your personal preferences for risk and equity fluctuations.

We next consider a delayed 20-bar breakout system with a $5,000 initial stop and a trailing stop at the 14-day high or low (case 5). The DM contracts over the same period for this case yielded a slope of $8.36, with a SE = $1,960. Case 5 had a clipped equity curve (see Figure 6.9) with many flat portions when the model was out of the market. The equity shows that this approach successfully caught some of the trends, and avoided most of the sideways markets.

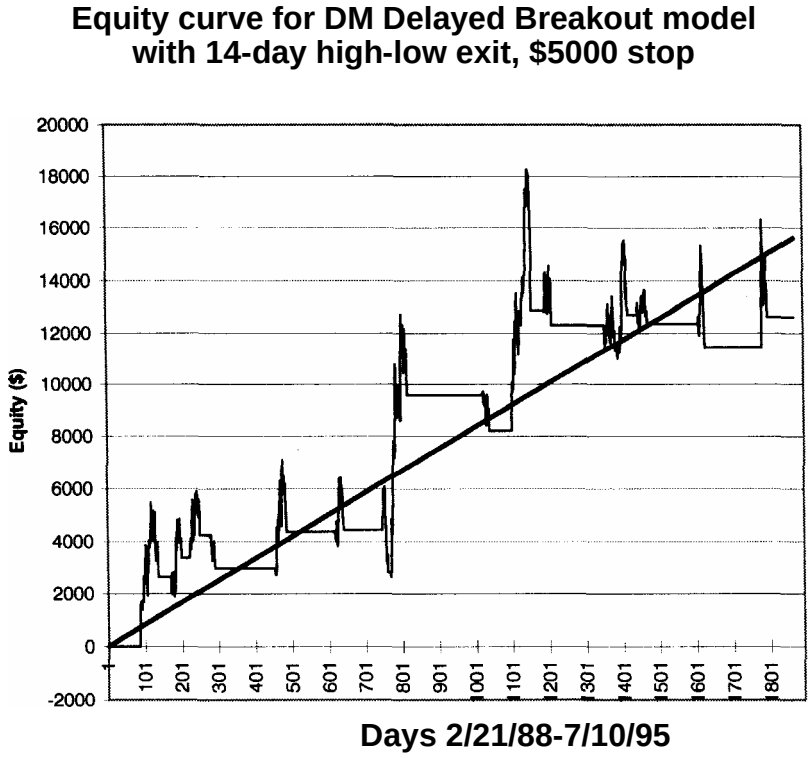

Figure 6.9 Equity curve for a delayed breakout model with $5,000 stop and 14-day high-low trailing stop (case 5).

You must be careful not to judge the relative smoothness of an equity curve simply by inspecting it visually. For example, consider case 6, the equity curve obtained by adding those for case 1 and case 5. This equity curve (Figure 6.10) seems smoother to the eye than the equity curve for case 1. Besides, we are adding an equity curve to case 1 that has just half of its SE. A regression calculation shows that the slope of the joint equity curve is $25.90 and the SE = $5,263, bigger than either curve. You may find this easier to believe if you grasp that the profitable periods coincide, increasing the amplitude of the movement during these overlapping periods. The result is an equity curve with larger standard error. Thus, you should check the regression numbers when you combine multiple systems on the same market.

Note that due to its greater slope, the composite equity curve (case 6) has a higher reward/risk ratio (25.90/5263 = 0.00492) then the original case 1 (17.54/4043 = 0.00434). Thus, we could improve the risk/reward ratio by combining systems using different logic to trade the same market.

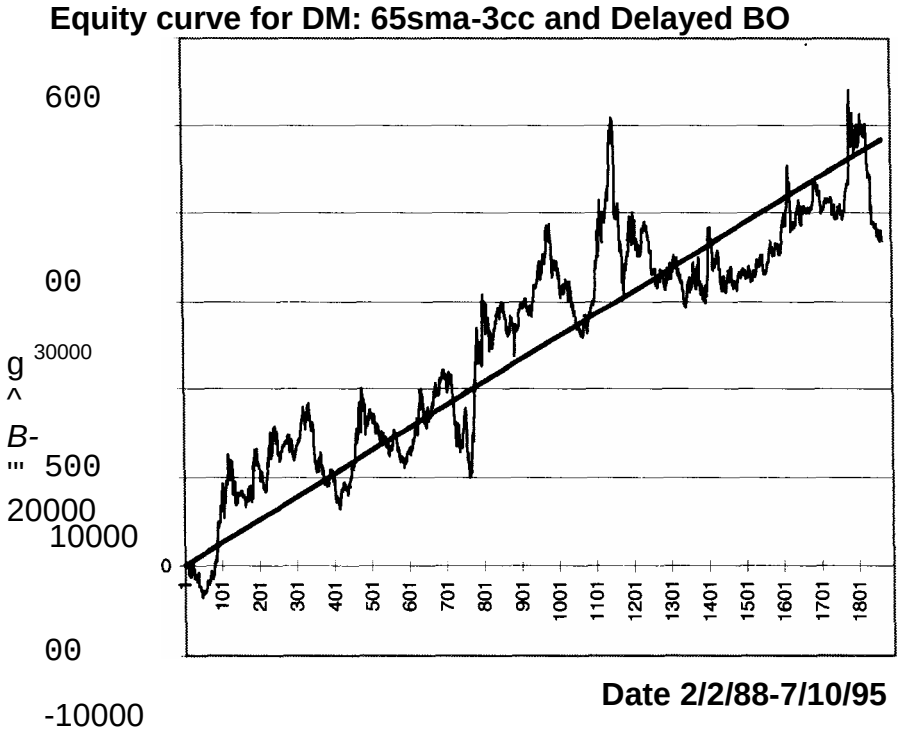

Figure 6.10 Case 6 combined equity curve for case 1 plus case 5.

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You should not underestimate the potential difficulties caused by positive covariance. Figure 6.11 shows the effect of combining two DM systems with positive covariance. The usual rules for combining variance of two independent systems predicted a standard error of $5,430. The actual calculated SE was $6,935, about 28 percent greater. The two systems have positive covariance because they tend to make (or lose) money at the same time, at least some of the time. Figure 6.11 shows lines one standard error on either side of the best fit line. These SE lines include most, but not all, of the points of the joint equity curves. The points that lie outside the SE bands occur when both systems "reinforce" each other, when they make money at the same time. Thus, combining systems with positive covariance will increase SE and reduce smoothness. Now add the complication that we do not know how covariances will change in the future. Therefore, improvements in smoothness may not result from simply adding different systems trading the same market.

One popular prescription for smoothing the equity curve is diversification through trading multiple markets. The equity curve for the cotton (CT) market, using the 65sma-3cc system from February 22, 1988,

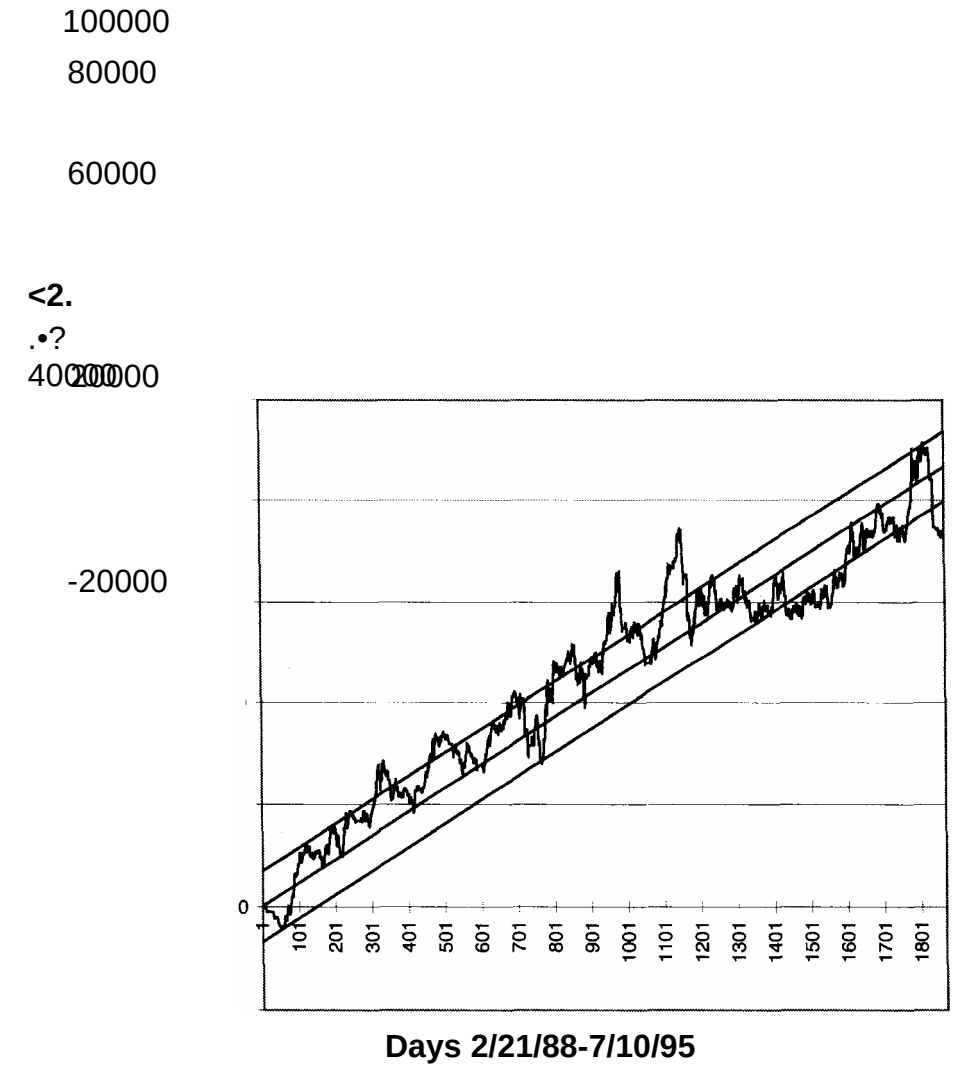

Figure 6.11 Trading two systems on the DM market with strong positive covari-ance increases SE and equity curve roughness. The lines above and below the best fit line are one standard error away.

through June 20, 1995, with a $5,000 stop is shown in Figure 6.12. The system reported a profit of $28,720, with a profit factor of 1.64, and a maximum intraday drawdown of-$7,120. As usual, $100 was allowed for slippage and commissions in these calculations. Regression calculations showed a slope of 11.65 and a SE of $3,184. The 65sma-3cc calculations for DM for the same period and conditions as the CT calculations yielded profits of $24,900 with a profit factor of 1.34 and a maximum intraday drawdown of-$11,687.

The CT and DM equity curves to test for increased smoothness. The assumption here is that the CT and DM markets are not dependent on each other. The regression analysis of the joint CT plus DM equity

curve (Figure 6.13) showed a slope of $29.34 and a SE of $5,265. The increase in slope is understandable, since adding the two markets roughly doubled the profits over the same period. The joint slope for CT and DM is the sum of their individual slopes ($29.34 = $11.65 + $17.69). The rules for combining variance suggest that if the

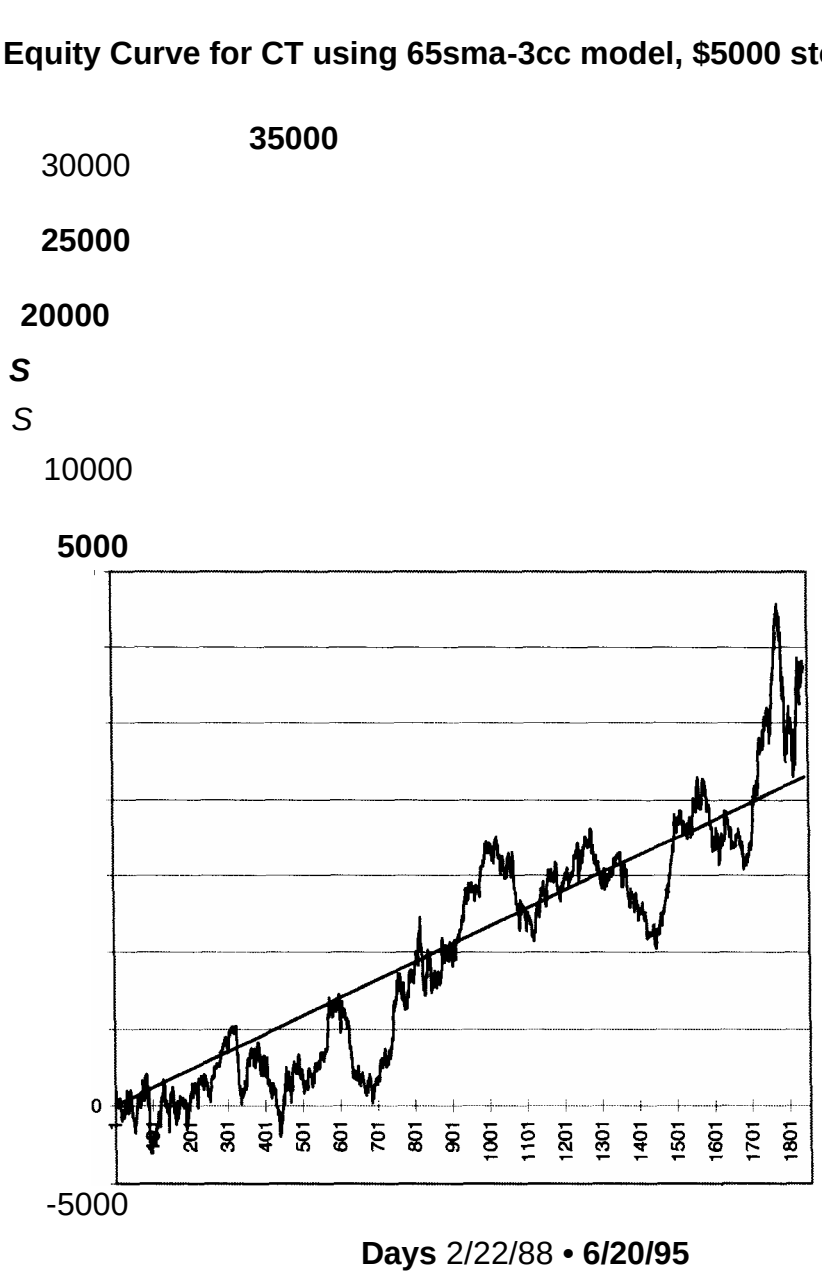

Figure 6.12 Equity curve for CT using the 65sma-3cc system.

two markets were independent, then their variances (squared standard error) would just add up linearly. This indicates that the expected value of the standard error for the joint CT + DM equity curve is $5,098. However, we see that the actual value is slightly higher, at $5,264, implying some positive covariance. Thus, we could not have reduced equity curve roughness by combining these two markets. We can show that adding more markets to a portfolio does not increase smoothness (reduce SE) unless the two markets are negatively correlated. Usually, there is some weak correlation between markets due to random or fundamental factors, and markets rarely move exactly opposite to each other. Hence, we should expect roughness (or SE) to increase as we

combine the equity curves from different markets.

In summary, the SE of the equity does not automatically decrease when you change exit strategies, combine different systems on the same markets, or combine different markets on the same system. However, changing entry strategies can change SE significantly. This conclusion goes a bit against the popular wisdom that "diversification" gives a smoother equity curve. Diversification in this context means trading

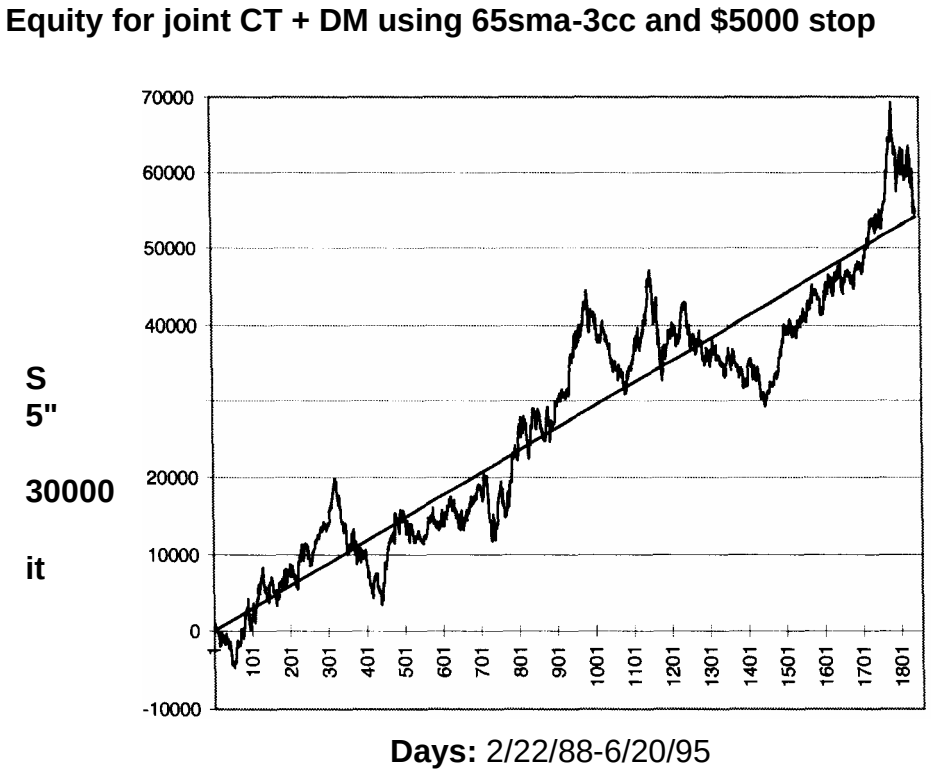

Figure 6.13 The joint CT + DM equity curve.

many different markets with the same system, or the same market with many systems. Of course, we are measuring the smoothness using the standard error from linear regression analysis. We saw in the previous section that increasing the slope does not reduce the SE.

You should use the information in this section to understand how system design and portfolio strategies can affect the smoothness of your equity curve. In this section we examined the daily equity curve for individual markets or systems. In the next section we look at the monthly equity curve and how it changes with money-management rules.

Analysis of Monthly Equity Changes

The impact of a given system on your equity curve will depend on system design and money-management decisions. In this section we look at the monthly equity curve, to understand month-to-month performance. We follow standard accounting procedures and look at the profit and

loss figures at the end of each month. You may wish to look at the equity curves on a weekly basis, but the random noise in the market often complicates the analysis of such detailed data.

We saw in the previous section that the standard error of the linear regression provides an excellent measure of the roughness of the equity curve. However, the linear regression approach does not show how much money the system lost over a 1-, 2- or 3-month period, nor does it reveal the maximum cumulative loss. We also would like to know what percentage of the months showed profitable returns, and whether the curve becomes smoother when we add certain markets or change the portfolio mix. Another useful bit of information is how quickly the system recovers from a losing streak, measured in months between new highs.

"You must remember that this analysis reflects past data, not how the system will do in the future. However, if you use average numbers and standard deviations, you can get a fair estimate of future performance. *You* can then decide how to capitalize the system, by quantifying the equity swings you can tolerate. Thus, analyzing the equity curve on a portfolio basis gives a deeper understanding of system performance, and you can better prepare for future equity swings in real-time trading.

Most of this analysis was done in a spreadsheet, since the popular system testing software does not provide this information. We first used Omega Research's System Writer Plus™ software to generate the daily equity curve using real contract data with rollovers, because we found that continuous contracts were not giving reliable results. We then used Tom Berry's Portfolio Analyzer™ software to summarize these data into monthly performance numbers. You can do the same using a spreadsheet, or you can write a simple program.

Once in the spreadsheet, we calculated the actual dollar changes in equity over 1, 2, 3, 4, 5, 6, and 12 months. We could then quickly calculate the best performance, the worst performance (drawdown) and standard deviation of profits over each period. The advantage of making the dollar equity change calculations was that we could clearly see the effects of a particular exit strategy or of combining different markets in a portfolio. Some sample calculations will give you a feel for analyzing equity curves at a portfolio level.

We used actual DM contracts from automatic rollover on the 20th day of the month preceding expiration. The test period was February 1988 through June 1995. We allowed $100 for slippage and commissions and used the 65sma-3cc system with one-way entries to test different exit strategies. A one-way model does not allow back-to-back entries of the same type, so that you will not see two consecutive long or short

trades. Thus, the number of entries over a data set is constant, allowing an apples-to-apples comparison.

Figure 6.14 is the monthly equity curve for the 65sma-3cc system with a $5,000 initial stop and no other exits. Thus, the long entry was also the short exit signal, and vice versa. The large stop makes it a better test of the inherent robustness of the entry signals. The system reported a paper profit of $24,900 from February 22, 1988 through June 20, 1995, with a profit factor of 1.34, 35 of 70 profitable trades, and a drawdown of-$11,687.

The monthly equity curve (see Figure 6.14) shows the overall rising trend with many sharp equity retracements, which occurred during trading range markets following a strong trend. Interestingly, rolling over the contract captured most of the profits in an uptrend, better than most exits. However, the system gave up most of the profits in the consolidation that followed the uptrend, suggesting that filtering this model should smooth out the equity curve. You could have deduced this information by studying the charts of each contract tested. However, the eq-

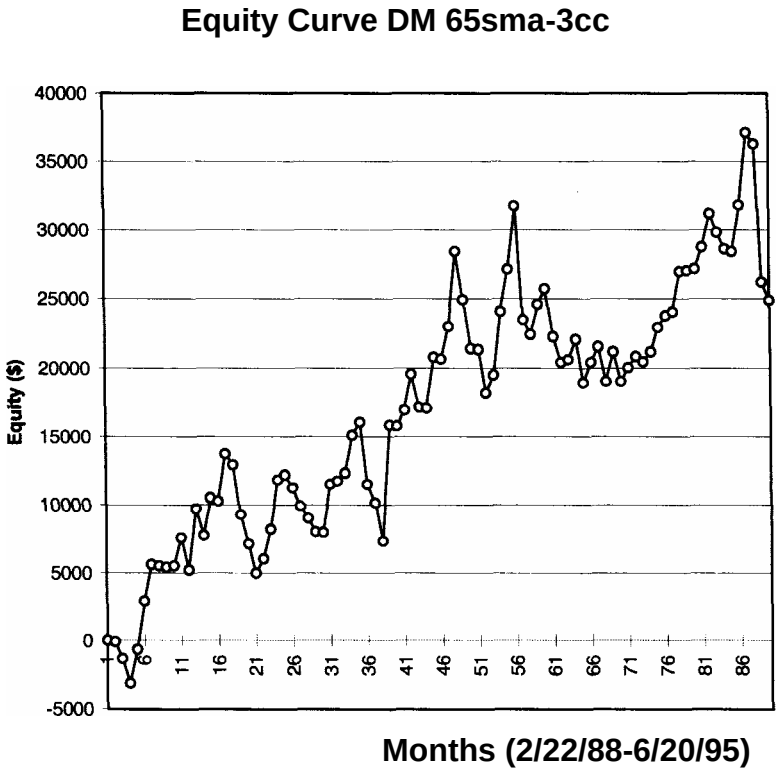

Figure 6.14 Monthly equity curve for deutsche mark calculations with rollover contracts.

uity curve clearly shows a need to check those charts if you had not checked them already.

Our usual summary does not tell us what the equity changes are over periods of 1, 2, 3, 4, 5, 6, or 12 months. Yet we need this type of information to understand the impact of the trading strategy on account equity. So, let us review how the 65sma-3cc system did over different time intervals. Figure 6.15 is a plot of the worst drawdown over any consecutive periods of 1, 2, 3, 4, 5, 6, or 12 months. The drawdowns were in the range of-$9,000 to -$13,000. This is the maximum peak-to-valley reduction in equity over the monthly period of interest.

You will recognize that such a drawdown is meaningful only in the context of your account equity. Thus, if you traded this system with a $25,000 account, it would suffer drawdowns greater than 20 percent, suggesting you should trade this system with $50,000 or more of equity per contract traded.

Another important piece of information we can gather from the equity analysis is the percentage of intervals that were profitable. This

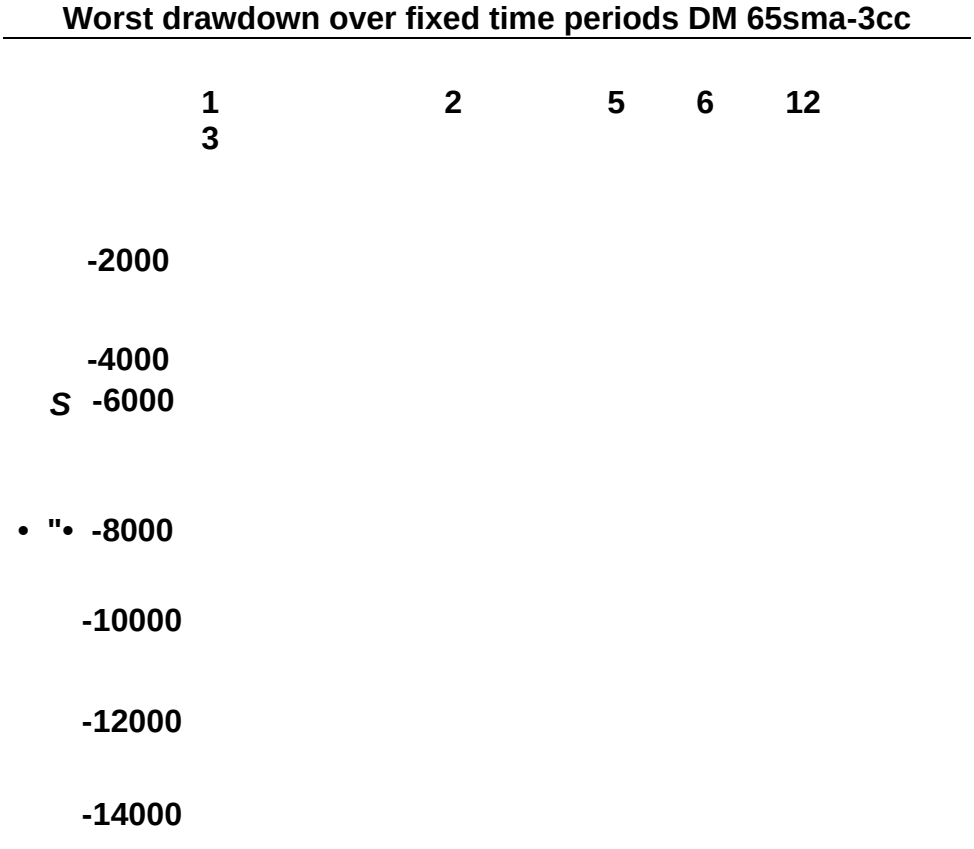

Figure 6.15 Maximum losses in DM over fixed monthly intervals from February 1988 through June 1995.

will show what percentages of consecutive months were profitable on a monthly basis, a useful measure of system performance. Figure 6.16 shows these data for the DM test with 65sma-3cc. More than 50 percent of the 90 monthly intervals from February 1988 through June 1995 were profitable. The proportion of winning intervals increases as the period increases. This could be interpreted as the longer you are in a drawdown mode, the more likely you are to come out it.

You should take a good look at the proportion of profitable intervals for each market when you combine different markets hoping to increase the proportion of profitable intervals. A good measure of your successful diversification processes is upward changes in the proportion of profitable intervals. Here diversification includes multiple markets, multiple trading systems, and different money-management strategies.

You should also look at the standard deviation of monthly equity changes. You can use it to project drawdowns for this system. This idea is explored in the next section. For now, we will test the effect of adding a $1,500 trailing stop to the 65sma-3cc model using actual DM con-

Percentage of profitable intervals (90 total) for DM using 65sma-3cc

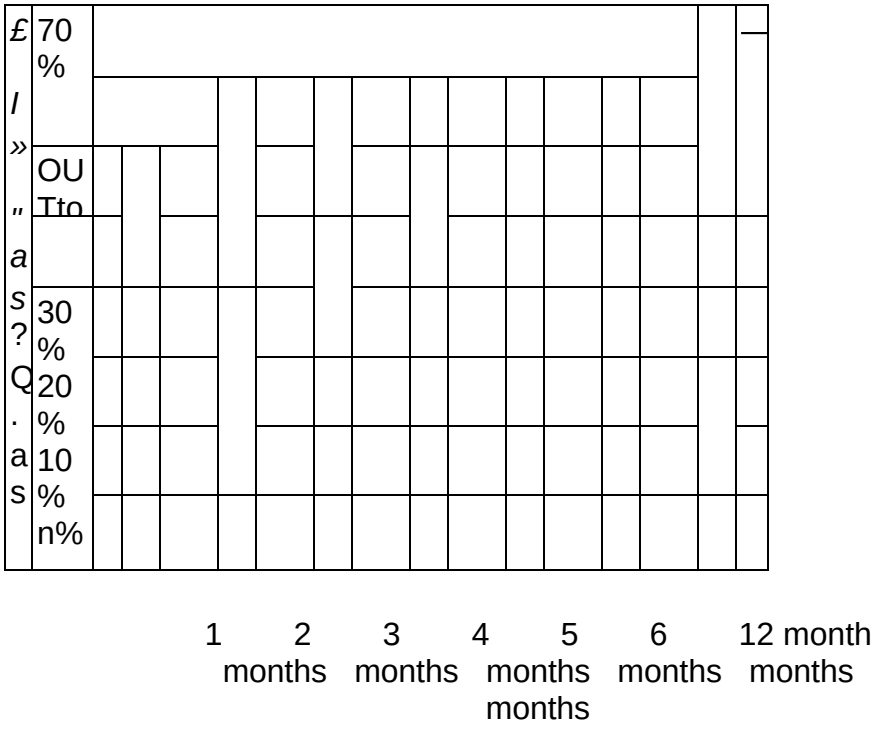

Figure 6.16 Proportion of profitable intervals shows that this system tends to have fewer unprofitable intervals as the length of the interval increases.

tracts with rollovers and a $5,000 initial stop. As usual, we allow $100 for slippage and commissions. The $1,500 stop trails from the point of highest equity for long and short trades. The net paper profit was $7,500, with a profit factor of 1.12, and a drawdown of-$15,515. These results were somewhat worse than not using a trailing stop at all. However, the net profit analysis does not provide the additional insight sketched below.

Figure 6.17 compares the average monthly equity changes with and without a trailing stop for the 65sma-3cc system. There is litde doubt that the trailing stop significantly reduces average monthly performance. You should expect the drop in monthly performance since the net profit with the trailing stop was $7,500 versus $24,900 without the trailing stop. A key point not evident from the profit summary, but clearly visible in Figure 6.17 is the performance at the 12-month level, which strongly favors not using a trailing stop.

Unfortunately, the trailing stop also had the effect of reducing the proportion of profitable intervals. The trailing stop did litde to improve

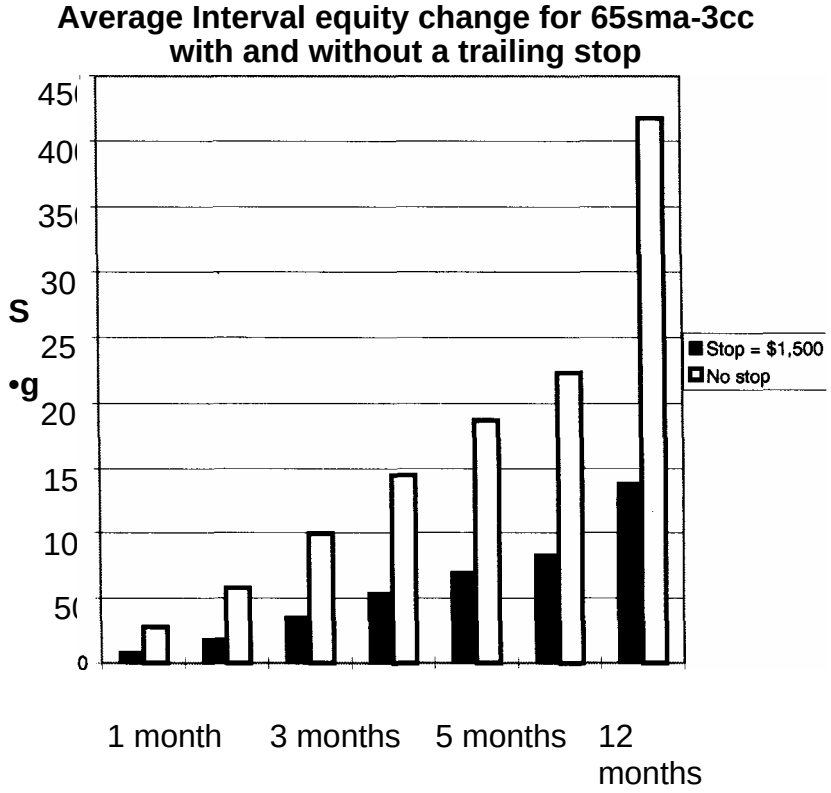

Figure 6.17 The average profit over each monthly interval was substantially better without the trailing stop, suggesting that many trades were cut off prematurely. The unmarked bars are for 2 months, 4 months, and 6 months.

the smoothness of the equity curve. For example, the standard error with the trailing stop was 3 percent higher, at $4,087, even though profits plummeted nearly 70 percent.

Deleting the trailing stop and adding an exit on the twentieth day of entry increased the reported profit to $14,950 (versus $7,500 with the trailing stop) with a profit factor of 1.27, and drawdown of -$11,325. These data are virtually the same as those with a $5,000 initial stop. Hence, there should be little change in portfolio level performance as a result of adding this exit.

The new SE was 10 percent smaller, at $3,781, but the performance over the intervals was comparable to tests without the stop. Hence, adding this exit produced little improvement, but cost a 40-percent drop from $24,000 in potential profits. Although not shown here, the proportion of profitable intervals dropped about 10 percent, another strike against this exit strategy.

A number of other exit strategies yielded similar results: none improved smoothness of the equity curve by more than 10 percent, a few worsened it, and most had a heavy profit penalty. Changing exit strategies often seems to degrade month-to-month performance. Hence, in the next section we will try to get a smoother equity curve by changing system design.

Effect of Filtering on the Equity Curve

Filtering is a way to reduce the number of trades and provide better entries into the trade. Filtering can also produce a smoother equity curve. We saw that we could not improve smoothness (reduce standard error) with exits alone. Of course, you can argue that there might be other exits that work better, and you can check them all if you like.

In order to get a smoother equity curve, we will try changing the system design by introducing a filter. Because losses come from entries during consolidations, the primary benefit of filtering would be to eliminate some of the unprofitable entries. The penalty would be late entry into trends, resulting in lost profits. In some cases, the late entries would be near intermediate tops or bottoms, with the market reversing into the previous consolidation region. Such trades would trigger the initial stop loss orders. We explored how to use the RAVI filter with the 65sma-3cc system in chapter 3. *You* can use momentum-based filters or invent other filtering schemes.

We tested a breakout system because breakout systems inherently do not produce entries during small consolidations. For example, a narrow consolidation will not produce new 20-day highs or lows. Therefore, entries from the 65sma-3cc system in these areas would be eliminated. We used a simple filter based on the directional movement index (DMI) because it is a bit more sensitive than the average directional index, or ADX. The purpose of the filter is just to reduce false breakouts, since breakouts during wide consolidations will occur without strong market momentum. The filter merely stipulates that the 14-day DMI be greater than an arbitrarily chosen level such as 50. For details on the construction of the DMI please refer to Wilder's book (see bibliography for reference).

We tested the system on DM data from March 1988 through June 1995 with rollovers on the twentieth day of the month before expiration, a $1,500 initial stop, and $100 allowed for slippage and commissions. The equity curves for the filtered and unfiltered system are shown in Figure 6.18.

Equity curves for filtered and unfiltered CHBO systems for DM

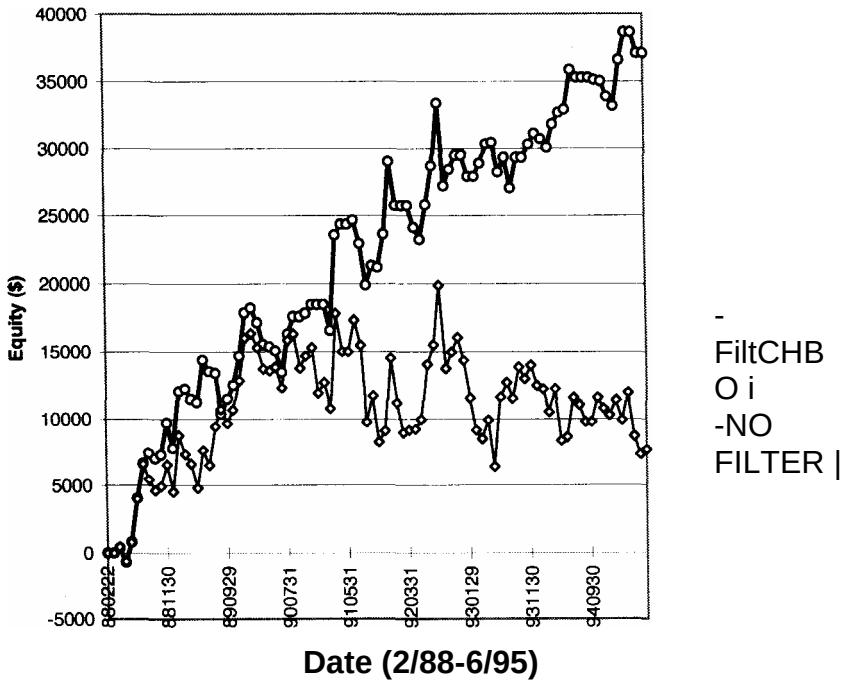

Figure 6.18 Equity curve for a 20-day channel system on DM with (upper line) and without (lower line) filter. Calculations are with rollovers on actual daily contract data.

Filtering also produced an equity curve (see Figure 6.19) that is smoother than for the unfiltered 65sma-3cc system, described in this chapter as case 1. Note that the case 1 equity curve has been converted from daily to monthly data. The SE for case 1 was $3,776, versus $2,507 for the filtered equity curve, a difference of 50 percent. The interval drawdowns were also smaller, confirming the smoother equity changes (see Figure 6.20).

We then compared the performance of the channel breakout system with and without filtering. The average interval equity change over 1, 3, 6, and 12 months was greater for the filtered system, as shown in Figure 6.21, page 204. Thus, the filtered system produced more consistent results for DM. For example, standard deviation of interval returns was greater for the unfiltered system (see Figure 6.22, page 205), confirming its uneven performance.

As expected, a linear regression analysis showed the standard error for the filtered system to be $2,507 versus $3,937 for the unfiltered system. Thus, filtering produced a smoother equity curve, since the stand-**Equity curves of 65sma-3cc and filtered channel breakout**

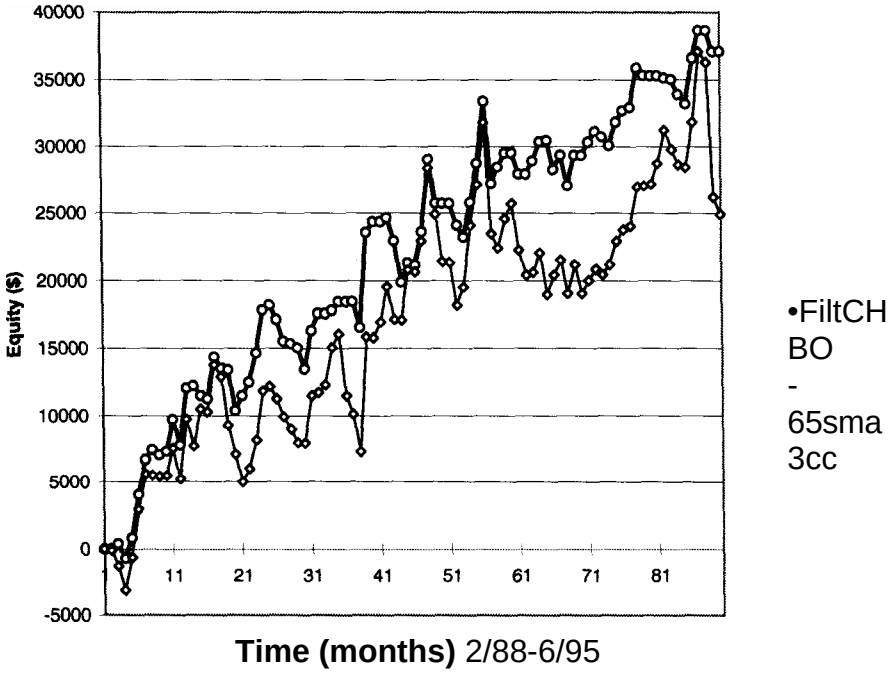

Figure 6.19 The filtered breakout system (upper line) had a smoother curve compared to the 65sma-3cc system without initial stop or exits (case 1; lower line).

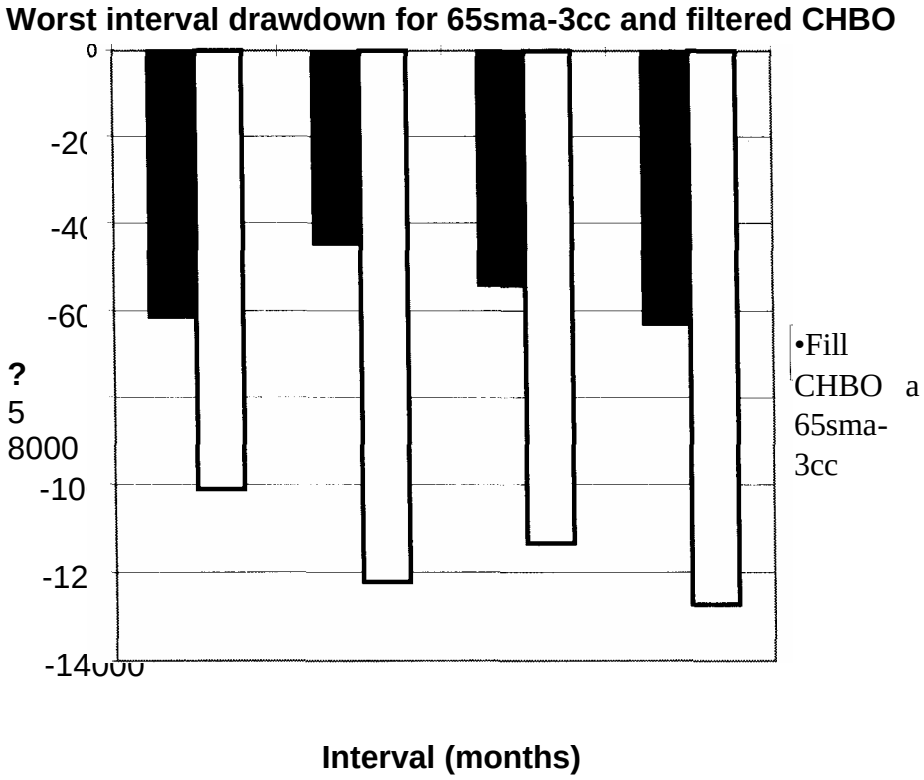

Figure 6.20 The filtered breakout system produced smaller drawdowns than the 65sma-3cc system without initial stop or exits (case 1). Data are for 1-, 3-, 6-, and 12-month intervals.

ard error decreased by 36 percent. A brief comparison of the filtered and unfiltered system is shown in Table 6.1.

The data in Table 6.1 show that filtering reduced the number of trades, and improved profitability and the profit factor in this instance. These calculations suggest that filtering can produce a smoother equity

Table 6.1 Comparison of DM systems

	Unfiltered	DM System	Filtered DM
Net profit ($)		6,863	37,125
Total number of trades		105	64
Percentage of winners		38	50
Ratio: average wins/losses		1.75	1.74
Average trade ($)		65	580
Maximum drawdown		-11.338	-5.688
Profit factor		1.08	1.74

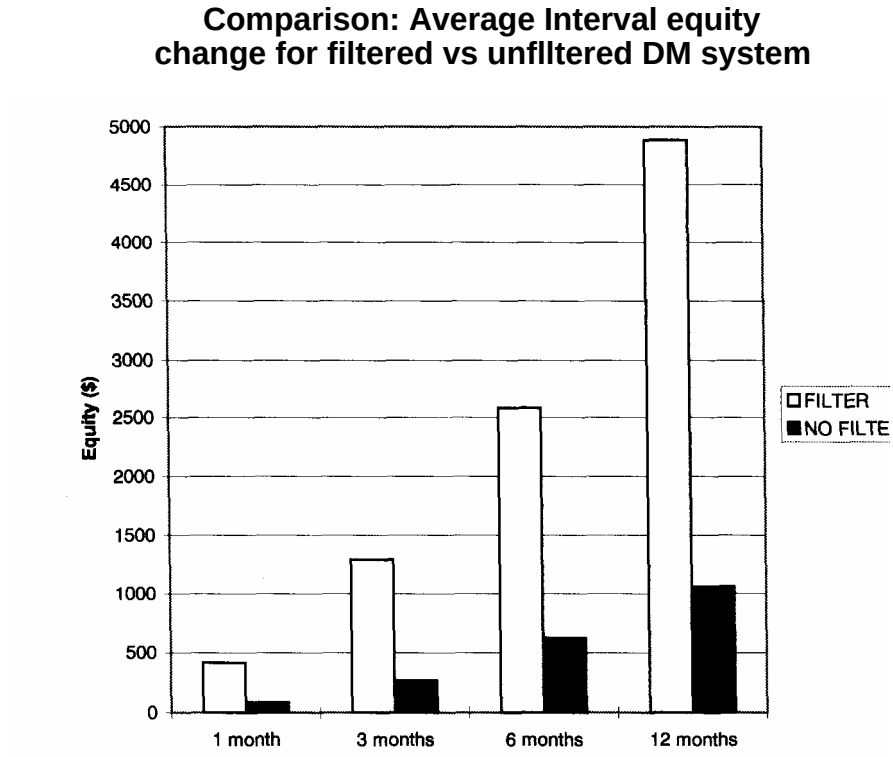

Figure 6.21 The interval equity changes were greater for the filtered deutsche mark system.

curve. Hence, you should also evaluate the effects of changing entry strategies at the portfolio level.

Summary

In this chapter we saw that the standard error from regression analysis is a good measure of the roughness of the equity curve. A smoother equity curve has a smaller value for the standard error.

We saw that the usual prescriptions for producing "smooth" equity curves do not work every time. Most exit strategies tested did not reduce the SE by more than 20 percent, but had a substantial profit penalty. Diversification over different markets or systems also increased standard error. We also examined monthly equity changes to confirm these findings. Only a change in entry rules gave a smoother equity curve.

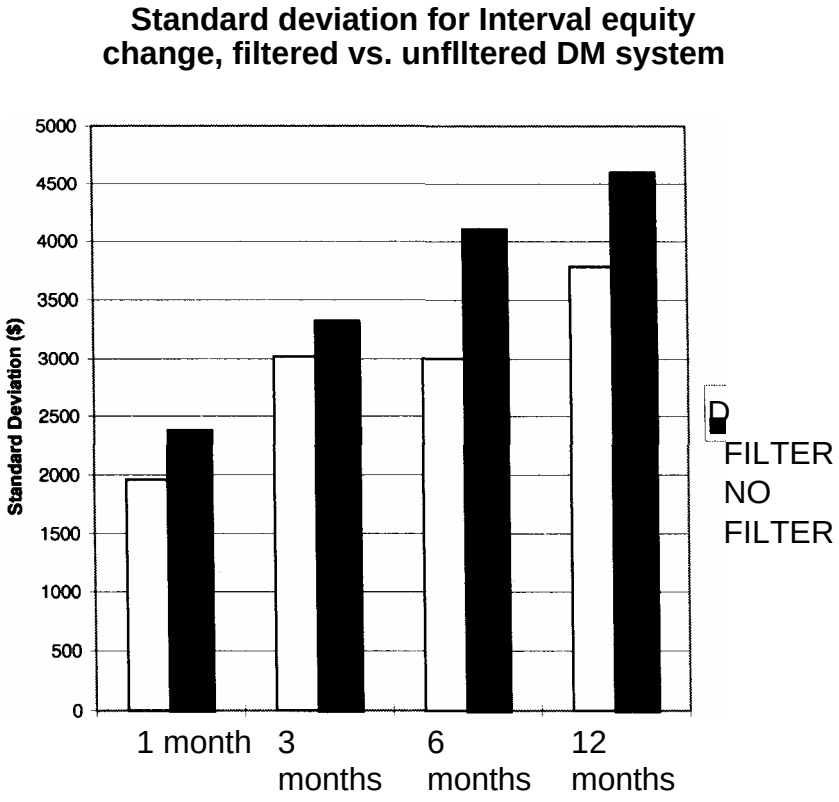

Figure 6.22 The unfiltered channel breakout system had larger standard deviation of interval equity changes.

This chapter showed that analyzing equity curves provides valuable insight into system design not available from the performance summary. Hence, no system development effort can be complete without examining equity curves.

Chapter

Ideas for Money Management

Bad money management will crush a good system.

Introduction

A big variable affecting the future performance of any system is money management. It is a major factor in properly implementing any trading system. There are many excellent books devoted just to this subject.

We begin by calculating the risk of ruin for the values you will meet during system testing. The data in the literature do not extend down to the range covered here. The risk-of-ruin calculations assume that your probability of winning and payoff ratio are constant. Since these values change from time to time, the risk-of-ruin calculations are simply for guidance.

We then study an example of the interaction between system design and money-management rules, and the effects of using fixed or variable contracts with a typical breakout system. We then expand on the theme of projecting drawdowns using the standard deviation of monthly equity changes. An out of sample test will convince you that it is reasonable to project future drawdowns with this method. It is very

useful to have a reasonable projection of future drawdowns because it helps you pick a suitable equity level for a system.

Lastly, we will see how changing bet size affects the equity curve. For a given system, you can change the smoothness of the equity curve by how you alter your betting strategy.

After reading this chapter, you will be able to:

1. Apply the risk-of-ruin ideas for money management.
2. Understand how system design and money-management rules interact with one another.
3. Project the range of possible future drawdowns for any system.
4. Develop strategies for changing bet size after winning and losing periods.

The Risk of Ruin

The mathematical calculations of the risk of ruin are the heart of your money-management rules. These statistical calculations assume that you play the game thousands of times with precisely the same odds. However, your trading situation does not fit this ideal in the real world. Nevertheless, you can best understand the hazards of leverage by studying the risk of ruin.

Using certain simplifying assumptions, the risk of ruin estimates the probability of losing all your equity. The goal of money management is to reduce your risk of ruin to, say, less than 1 percent. Here we follow the general approach used by Nauzer Balsara (see bibliography for reference; refer to this excellent book for more details).

There are three variables that influence the risk of ruin: (1) the probability of winning, (2) the payoff ratio (ratio of average winning to average losing trade), and (3) the fraction of capital exposed to trading. Your trading system design governs the first two quantities; your money-management guidelines control the third. The risk of ruin decreases as the payoff ratio increases or the probability of winning increases. It is obvious that the larger the fraction of capital risked on each trade, the higher the risk of ruin.

The estimates here follow Balsara's general simulation strategy to estimate the risk of ruin, except that we used a total of only 1,000 simulations (rather than 100,000 simulations) to estimate the probabilities. If

you can go broke in just 1,000 simulations, you probably would not survive 100,000 simulations.

Table 7.1 summarizes the risk of ruin if 1 percent of capital is at risk on each trade with a hard dollar stop. We looked at winning percentages ranging from 25 to 50 percent, and payoff ranging from 1 to 3. Most trading systems will show about 25 to 50 percent profitable trades.

This range of values is what you would typically see in testing. The 25 percent lower limit for profitable trades is a personal choice. The upper limit was chosen because the risk of ruin decreases substantially as the winning percentage goes beyond 50 percent. Similarly, it is relatively rare to get a payoff ratio greater than 3 when you test one contract per market. Conversely, there is little benefit to trading a system with a payoff ratio less than 1 unless it is very accurate and your transaction costs are small. The smaller bet size of testing (1 percent) is likely to be interesting because Balsara's book does not show risk of ruin for less than 10 percent risked per trade. The results generally agree with his calculations.

These theoretical calculations show that it is not attractive to trade a system with a payoff ratio near 1 unless it has a winning percentage greater than 50 percent. Similarly, the calculations show that if you have a payoff ratio greater than 2.5, then a winning percentage greater than 3 5 percent should reduce your risk to acceptable levels.

Tables 7.2 and 7.3 are for 1.5 and 2 percent of capital risked on each trade, respectively. Note how the risk of ruin increases as the amount risked increases, and decreases as the probability of winning increases or payoff ratio increases. These tables show why many traders recommend risking 2 percent per trade with a hard stop.

Table 7.1 Risk of ruin with 1 percent of capital at risk. A 0 probability means the total loss of equity is unlikely, but not impossible.

Probability of Winning(%)	Payoff				
	1	1.5	2	2.5	3.0
25	100	100	100	73	3.1
30	100	100	46.9	0.20	0
35	100	74.6	0.1	0	0
40	99.8	0.5	0	0	0
45	52.4	0	0	0	0
50	0	0	0	0	0

Table 7.2 Risk of ruin with 1.5 percent of capital at risk. A 0 probability means the total loss of equity is unlikely, but not impossible.

Probability of Winning(%)	Payoff				
	1	1.5	2	2.5	3.0
25	100	100	100	88.9	12
30	100	100	78.4	1.0	0
35	100	94.5	0.8	0	0
40	100	4.5	0	0	0
45	84.2	0	0	0	0
50	1.4	0	0	0	0

These calculations assume that the payoff ratio and probability of winning are constant. In reality, these numbers keep changing in time, and any estimates you have today will probably change in a few months. Thus, it is better to consider a range of payoff ratios and winning percentages when you consider your risk of ruin.

Looking at the problem from a different point of view, what would be the "magic" payoff ratios for a 1 percent risk per trade if your winning percentages ranged from 25 to 50 percent? The data in Table 7.4, which you can use as a quick reference when you evaluate system testing results, help to answer this question. For example, if the system had a winning percentage of 40 percent, then a payoff ratio above 1.75 would reduce your risk of ruin to manageable levels.

Table 7.3 Risk of ruin with 2 percent of capital at risk. A 0 probability means the total loss of equity is unlikely, but not impossible.

Probability of Winning(%)	**Payoff Ratio**				
	1	1.5	2	2.5	3.0
25	100	100	100	94.3	19.7
30	100	100	87.4	3	0
35	100	98.7	16	0	0
40	100	9.2	0	0	0
45	93.6	0	0	0	0
50	5.4	0	0	0	0

Table 7.4 Payoff ratio needed for negligible risk of ruin with a 1 percent hard stop

Probability of Winning (%)	Payoff Ratio	Risk of Ruin
25	3.25	0
30	2.75	0
35	2.25	0
40	1.75	0
45	1.5	0
50	1	0

Note the nonlinear nature of these relationships. For example, consider a payoff ratio of 1.5 and winning percentage of 40 percent. If you now change your risk per trade from 1 percent to 2 percent, the risk of ruin increases disproportionately from 0.5 to 9.2 percent (see Tables 7.1 and 7.3). Hence, there is little incentive to overleverage an account and consistently bet much more than 2 percent per trade. *You.* should also notice the benefits of modifying system design to improve the payoff ratio, or probability of winning, or both. The main advantage is that you can then increase the fraction of capital allocated to the system without unduly increasing risk.

These calculations do not mean you cannot vary bet size from trade to trade based on other information. For example, as Table 7.4 shows, if your probability of winning is greater than 50 percent and the payoff ratio is greater than 1, then the risk of ruin is very small. Thus, if you can find a mechanism to identify extraordinary opportunities, you can vary bet size. Such variations could significantly improve your overall results. See the section on identifying extraordinary opportunities in chapter 4.

In summary, the risk-of-ruin calculations show that there is little incentive to overtrade an account by regularly betting, say, 10 percent or more of account equity. A bet size of 1 to 2 percent of account equity is a more prudent choice. However, because the risk of ruin calculations assume that the probability of winning and payoff ratio are constants, and in actual trading, the probability of winning and payoff ratio vary from trade to trade, these risk-of-ruin results should be used only as general guidelines. They can be used to increase exposure for extraordinary opportunities.

This section examines the effects of two different money management strategies on portfolio performance. First we examine the effects of trading a system with a fixed or variable number of contracts. Then we see how portfolio performance differs for the two strategies. Finally, we check if our interval equity changes are useful for projecting worst-case drawdowns.

Vow goal is to take care of the downside, and let the market take care of the upside. *You* would like to maximize the rate of growth of account equity while managing the extent of cumulative losses. Money management involves all the decisions specifying amount of capital risked per trade. This, in turn, determines the number of contracts traded. The contracts traded impact the percentage of account equity allocated to margin dollars. Of course, you must also choose the markets traded in each account. *Yov.* can use relatively simple rules or relatively complex rules to make each of these choices, but your choice can significantly alter account equity evolution. *You* can also trade the same system with different money-management limits to produce significantly different results. This section briefly discusses common rules and shows their effects, but you should also review other books devoted just to this one subject.

The simplest risk control tool is an initial risk or money-management stop. This is usually a hard-dollar stop, with the dollar amount being usually less than 6 percent of your total equity. A hard-dollar stop is simply the amount of capital at risk per trade, usually implemented with a stop-loss order. Thus, you will exit the trade if the loss on all contracts approaches the hard-dollar stops. For example, we saw in the previous section that the usual choice is to risk 1 to 2 percent of your total equity on every position. Then, if your risk per contract is smaller than the total risk, you could trade more than one contract.

You. are making a trade-off between the rate at which you want your equity to grow and the drawdown you are capable of absorbing. Theories such as optimal-f use more complex formulas to increase equity growth beyond the one-contract-per-market approach. However, when you trade multiple contracts, the drawdown tends to increase, and hence money management becomes even more important.

We can examine the interaction between system design and money management by using a channel breakout system on the deustche mark using actual contract data with rollovers. The monthly equity curve for the system trading one contract with $100 allowed for slippage and

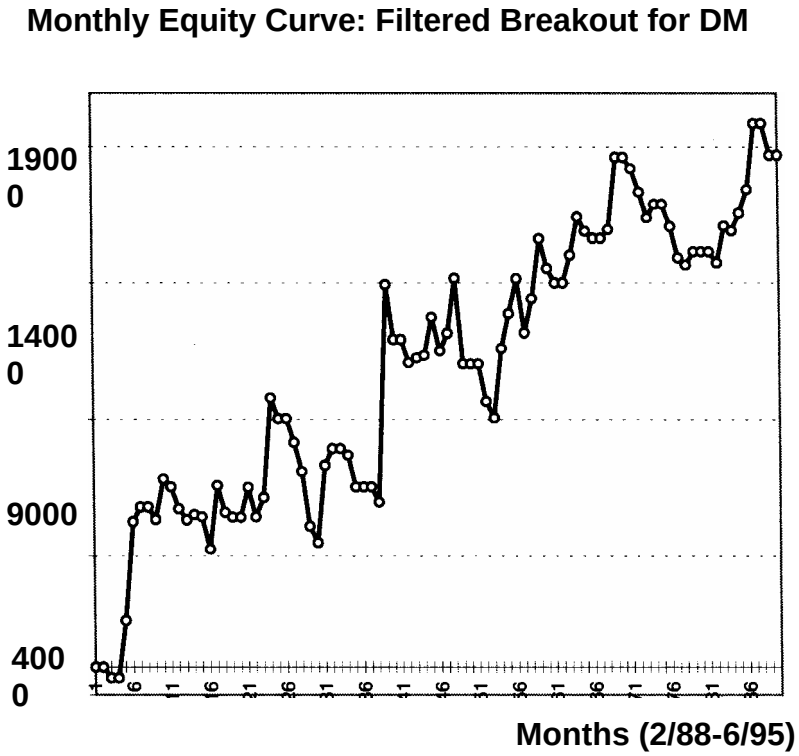

Figure 7.1 Monthly equity curve for deutsche mark trading one contract.

commission is shown in Figure 7.1. This system had a steady increase in equity with several significant retracements. We imported the monthly equity curve into a spreadsheet and analyzed the interval change in equity over 1, 3, 6, and 12 months. Those data appear in Table 7.5.

Some simple calculations will show the usefulness of Table 7.5. Assume that the monthly average return is zero and that monthly equity changes are normally distributed. Most trend-following systems have losing streaks lasting six months or less. Hence, to estimate downside

Table 7.5 Interval equity change analysis for the deutsche mark over 90 months (2/88-6/95)

Interval Analysis	1 Month	3 Months	6 Months	12 Months
Maximum gain	7,963	7,413	7,213	7,650
Maximum loss	-3.137	-3.925	-5.263	-3.889
Average ($)	208	651	1.297	2.111
Standard	1,471	2,263	2,667	2,928

potential, let us look at the worst loss over the 6-month interval. The maximum loss over six months was -$5,263, which is 3.5 times the monthly standard deviation of $1,471, rounded up to $1,500. We will use the 3.5 figure as a guideline, and round it up to 4. Thus, we will plan for a drawdown of four times the standard deviation of monthly equity changes. We know from statistical theory that the probability of getting a number larger than four times the standard deviation is quite small, about 6 in 100,000.

Now for a $50,000 account trading one deutsche mark contract for this system, our projected "worst" drawdown is 12 percent (= ($1,500 x 4) / $50,000). Using the same estimate for the upside, our "best" upside annual performance would be 12 percent. Thus, our most likely performance band will be ±12 percent. We can make this "linear" assumption because we are trading just one contract per market. Let us see how the system performed on an annual basis, assuming the account was reset to $50,000 at the beginning of each year.

Table 7.6 shows that the performance band of ±12 percent was generally a good estimate. The 10.5 percent drawdown trading just one contract (1990) is worrisome. To cut the figure in half, trade this system with an account equity of $100,000. However, doubling the equity will halve your return, and you will have to decide your comfort level between returns and drawdowns.

Now that you have some feel for how to deal with a single contract, let us consider the impact of trading multiple contracts. One method of selecting the number of contracts is to fix your hard-dollar stop, and then to use market volatility to determine the number of contracts. In such systems, the number of contracts is inversely proportional to volatility. When market volatility is high, you trade a smaller number of con-**Table 7.6** Annual return for DM system, $50,000 equity at start of year

Year	Percentage Return ($50K account)	Percentage Drawdown ($50K account)

1988	11.5	-1.9
1989	8.1	-2.5
1990	-6.5	-10.5
1991	15.3	-5.0
1992	-2.1	-10.2
1993	5.6	-2.4
1994	-2.9	-5.4

tracts, and vice versa. We have discussed volatility-based calculations before, such as for the long-bomb system in chapter 5. If volatility is $2,000, you buy five contracts for a $10,000 hard stop. If volatility triples to $6,000, you buy just one contract. *You* can use any measure volatility, such as the 10-day SMA of the daily range.

In trading terms, the volatility is often low at the start of a trend after the market has consolidated for a few months. Your volatility-based criterion will trade more contracts, giving you a big boost if a dynamic trend occurs. Conversely, near the end of a trend, the volatility is usually higher, and you will buy fewer contracts. Thus, any false signals near the end of a trend will have a proportionately smaller impact.

If the volatility-based logic worked perfectly, you would have greater exposure during trends and smaller exposure during consolidations. Thus, your overall results should improve "nonlinearly" with variable contracts versus trading a fixed number of contracts each time. For example, trading, say, eight contracts using a volatility-based entry criterion may be better than just trading a fixed number of eight contracts at every signal. You hope to achieve greater returns with smaller drawdowns (higher profit factor) using the volatility-based contract calculations. Figure 7.2 shows the effects of using a volatility-based multiple contract system using the breakout system for the deutsche mark. Compare this equity curve to the curve in Figure 7.1 for one contract.

The annual returns for the multiple-contract strategy are shown in Table 7.7. The multiple-contract system made more than five times the profit of the single-contract system. The system traded a maximum of eight contracts, and an average of three contracts. The drawdowns were, on average, only three times higher. Thus, there was a significant im-

Table 7.7 Annual return for deutsche mark system, $50,000 equity at start of year, multiple contracts

Year	Percentage Return ($50K Account)	Percentage Drawdown ($50K Account)
1988	**102.8**	**-4.0**
1989	**44.5**	**-5.9**
1990	**-24.7**	**-43.6**
1991	**-15.1**	**-11.8**
1992	**-6.2**	**-30.5**
1993	**20.6**	**-6.0**
1994	**-15.7**	**-23.4**

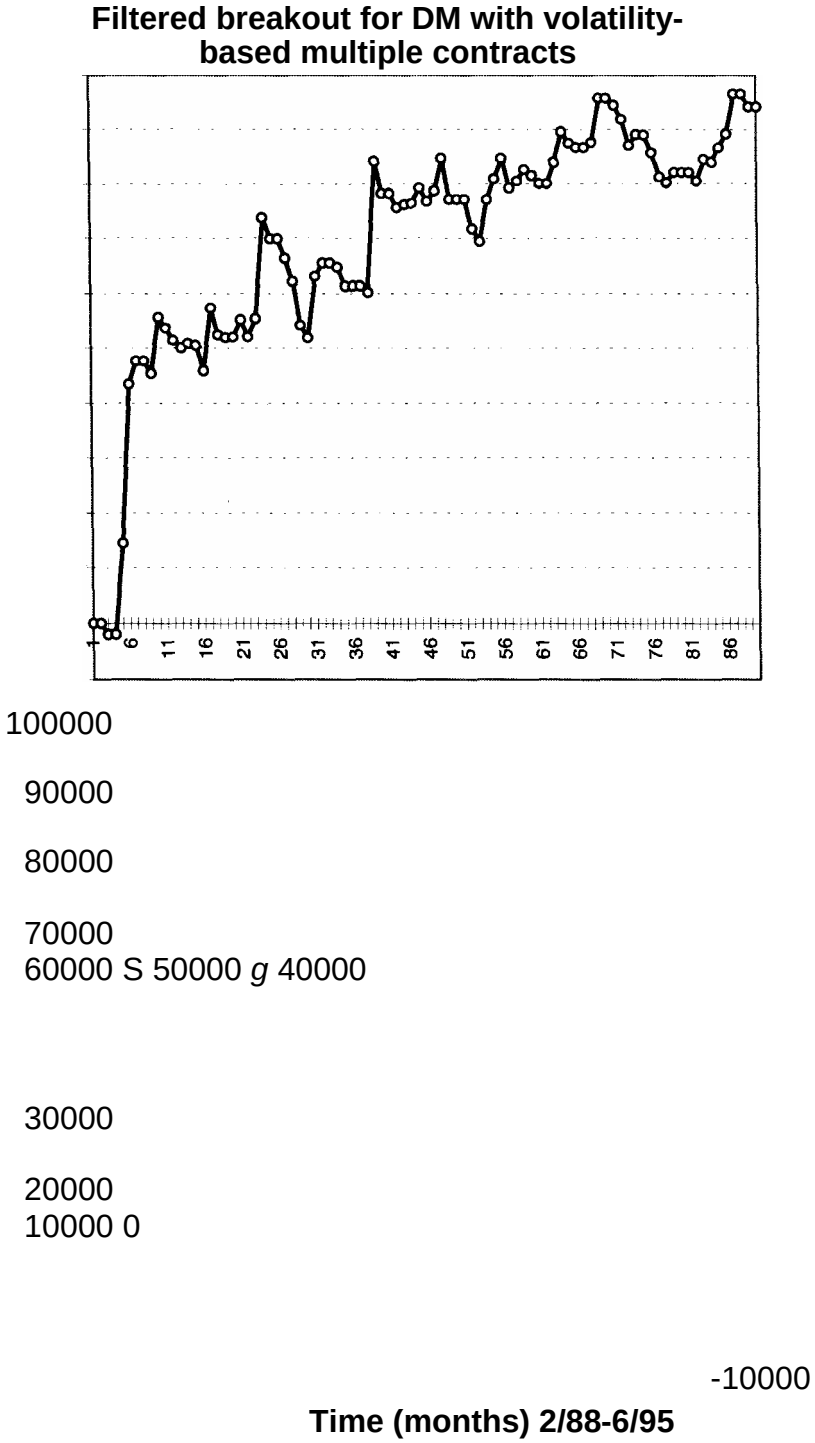

Figure 7.2 Equity curve for deutsche mark system with multiple contracts.

provement in performance by going to a multiple-contract strategy. Of course, the drawdowns were higher as well. Let us look at the interval returns to better understand system performance.

Comparing Tables 7.5 for one contract and 7.8 for multiple contracts, you will see the big difference due to the variable contract strategy, since the quantities are three to four times larger in Table 7.8. For

example, if we traded five contracts for the DM system from Table 7.5, the maximum drawdown for the 6-month interval would be -$26,315 (= 5 x $5,263). The variable-contract strategy (Table 7.8) produces a maximum 6-month loss of-$21,800, 17 percent smaller than the fixed 5x strategy. However, the fixed 5x strategy produces the same nominal net profit as the variable contract strategy. Thus, the "nonlinearity" of the variable-contracts logic can produce interesting results.

As in the single contract strategy, we round up the 1-month standard deviation to $6,000 and use a 4x multiple, to estimate -$24,000 as the "worst" drawdown. Thus, for a $50,000 account this would be a performance band of 48 percent. It should be immediately obvious that we are practically overleveraging a $50,000 account with this multiple-con-

Table 7.8 Interval equity change analysis for the deutsche mark over 90 months with multiple contracts (2/88-6/95)

Interval Analysis	1 Month	3 Months	6 Months	12 Months
Maximum gain ($)	28,900	49,500	57,575	52,413
Maximum loss ($)	-7,950	-15,700	-21,800	-15,213
Average ($)	1,047	3,238	6,432	9,479
Standard deviation ($)	5,923	10,613	13,944	14,963

tract system. Comparing Table 7.6 for single contracts with Table 7.7 for multiple contracts, observe that in 1991, the 1-contract system made a 15.3-percent profit, versus a 15.1-percent loss for the multiple-contract system. It is not recommended that you trade an account with so much leverage, and these calculations emphasize this point.

When you increase the amount of account equity, it reduces the fluctuations in equity on a percentage basis. Hence, when you calculate a linear regression on the percentage changes in equity, then you get a smoother curve by using a smaller leverage. This is only natural, since the equity in the account acts like a buffer to absorb small fluctuations when you reduce leverage. *You* can see this pattern clearly in Table 7.9, which shows the standard error for account sizes of $50,000, $75,000, and $100,000 for the data shown in Table 7.5.

A decrease in the standard error means the equity curve is smoother. As the size of the account increases, the percentage fluctuations decrease. Note that our estimated performance band was a good guess about drawdowns. Thus, the 1-month standard deviation of equity returns times four may be a good starting point to estimate downside risk. You can then deduce the account size to maintain a low level of drawdowns. Say you trade six markets, and want to limit the "worst" drawdown to 3 percent. Then you would trade the multiple contract system with an account equity of $800,000. This is very different from the $50,000 account.

Table 7.9 Smaller leverage gives a smoother equity curve on a percentage basis

Account Size	Standard Error of Monthly Changes (%)

$50,000	2.94
$75,000	1.96
$100,000	1.47

The results and discussion of this section should convince you that money management strategies can significantly alter portfolio performance. As stated previously, as a design philosophy, you should try to protect the downside and let the market take care of the upside. In the next section we examine if it is possible to estimate future drawdowns using our interval analysis of the equity curve.

Projecting Drawdowns

A key money-management goal is to protect the downside using rigid risk control. We would therefore like to make reasonable projections about potential drawdowns. We have to rely on past analyses to forecast the future, so we should try to err on the side of caution, and bias our forecasts toward the high side. It is better to plan for a larger drawdown than a smaller one.

The previous section suggested that the standard deviation of monthly equity changes for a system is a reasonable tool to project the magnitude of future losses. We first developed the daily equity curve, then converted it into a monthly equity curve, and then calculated the monthly changes in equity. Using spreadsheet software, we can also calculate the standard deviation of monthly equity changes. Let us call this quantity <7i for convenience. A conservative forecast for future drawdowns is 4oi for any system. However, this is only an estimate, and you could consider other nearby values such as 5oi or even 3ai.

To test this forecasting technique, we used continuous contracts from January 1, 1985, through December 31, 1990, for these seven arbitrarily selected markets: cotton, Eurodollar, gold, heating oil, Japanese yen, Swiss franc, and U.S. bond. We tested three arbitrary, nonop-timized systems: the 65sma-3cc, a 20-bar breakout on close (CHBOC) with a 10-tick barrier, and a volatility-based system (VOL). The rules for this last system are described in detail in chapter 8 on data scrambling. We used a $2,500 initial stop and an exit on trailing 10-day high or low, and allowed $100 for slippage and commissions. These choices were all made arbitrarily, without any idea of how the systems will perform and without looking at the data.

The logic for entering the markets is quite different for each system, although they have the same exit strategy. Hence, being trend-following in nature, they should all be profitable in trending markets. It is their response to sideways markets that will differentiate system performance. The 65sma-3cc system will probably show smaller losses,

Table 7.10 Simulated profits and drawdowns for the 1985-1990 period (Max P = net profit, MIDD = maximum intraday drawdown)

Market	CHBOC MaxP (S)	CHBOC MIDD ($)	VOL. MaxP (S)	VOL. MIDD (S)	65sma-3cc MaxP ($)	65sma-3cc MIDD
Cotton	5,245	-16,005	27,165	-7,330	20,675	-5,815
Eurodoll	13.950	-1.750	9.475	-8.725	9.675	-4.275
Gold	-10.330	-16.200	-1.170	-12.790	-4.280	-10.280
Heating	15.382	-20.751	-32.825	-50.571	21.761	-13.380
Japanes yen	38.663	-11.513	59.913	-8.938	13.475	-11.113
Swiss	1.450	-18.663	35.075	-18.750	12.350	-11.400
U.S.	17.513	-10.400	49.413	-9.125	-17.025	-28.438
Totals	81,873	-95,282	147,046	-116,229	56,631	-84,701

since it tends to be self-correcting during trading ranges. The CHBOC 20-bar breakout will stay out of narrow trading ranges, but will suffer false breakouts during broad trading range markets. The volatility system will be vulnerable to sharp moves within the trading range.

By examining overall system profits and maximum intraday losses, you can better appreciate the analysis of monthly equity changes. Tables 7.10 and 7.11 show that there were wide differences in overall profitability and drawdowns for the three systems over the seven markets.

Table 7.11 Simulated profits and draw downs for the 1991-95 period (Max P = net profit, MIDD = maximum intraday draw down)

Market	CHBOC MaxP ($)	CHBOC MIDD	VOL. MaxP ($)	VOL. MIDD ($)	65sma-3cc MaxP ($)	65sma-3cc MIDD
Cotton	18,430	-5,265	9,195	-11,425	33,060	-8,940
Eurodoll	3.850	-2.200	350	-4.675	1.525	-2.225
Gold	-12.630	-12.630	-17.750	-18.660	-870	-2.510
Heating	-7.080	-15.813	-24.330	-25.296	-5.113	-10.261
Japanes yen	19.563	-11.200	27.463	-1 3.925	44.500	-3.538
Swiss	17.925	-9.000	18.700	-10.850	5.750	-12.313
U.S.	-7.531	-19.756	-1.288	-9.556	^t.538	-10.706
Totals	32,527	-75,864	12,340	-94,387	74,314	-50,493

The 65sma-3cc system produced the smallest total drawdown, followed by the CHBOC system. Note the large drawdowns produced by the volatility system in heating oil from 1985 to 1990. Gold, heating oil and U.S. bonds were difficult to trade with these systems. Note also the large fluctuations in profits and losses over the test periods. You should focus on relative differences in system performance.

We would like to see if this interval analysis can project future drawdowns. Hence, we exported the daily equity curves, converted them into monthly curves, and used a spreadsheet to develop information on changes in equity over 1, 3, 6, 7, 8, 9, and 12 months.

In most systems tested, the periods of drawdown usually last less than 9 months. Hence, we paid greater attention to the 6- to 9-month range. We calculated the standard deviation of the monthly equity changes, and then determined the worst performance over any of the above intervals, hoping that the ratio of the worst interval performance to the standard deviation of monthly equity changes would be 5 or less.

The equity calculations were repeated for the next block of data, from January 1, 1991, through June 30, 1995, without changing the system. The new test period was an "out of sample" test to check stability. We then did the interval equity change calculations in a bid to see if the forecast for the worst drawdown based on the data from 1985 to 1990 had held up on the data from 1991 to 1995. Ideally, the standard deviation of monthly equity changes would be roughly comparable in the two periods, to reinforce our confidence in this approach.

Table 7.12 shows the standard deviation of monthly equity changes and maximum drawdown for the three systems over each period. The monthly standard deviation was quite stable. The ratio of the average loss was approximately four times the monthly standard deviation over both time periods. This is encouraging, since we did an "out of sample" test without optimization using arbitrarily selected systems and markets. These data show that it is reasonable to project future drawdowns by using the standard deviation of monthly equity changes, assuming a potential loss of four to five times the monthly standard deviation.

Once you know the projected loss, you can immediately gauge a possible equity level to trade the system or portfolio. Let us say you wanted to keep the drawdowns below 20 percent. To be safe, let us use a target of 15 percent, with a 5-percent cushion for future uncertainties. Hence, if you had a calculated standard deviation of $6,000, then a 5x forecast would be a drawdown of-$30,000. Since we want to keep projected drawdowns at the 15-percent level, the approximate equity level is $200,000 for trading this system or portfolio.

Table 7.12 Comparison of standard deviation and theoretical losses for three systems over two different time periods using monthly changes in equity

System	Monthly Deviation (1985-1990) ($)	Worst Drawdown (1985-1990) ($)	Ratio of Worst Drawdown to Standard Deviation (1985-1990)	Monthly Deviation (1991-1995) ($)	Worst Drawdown (1991-1995) ($)	Ratio of Worst Drawdown to Standard Deviation
CHBOC	6,879	-21,977	3.2x	5,944	-28,587	4.2x
VOL	4.229	-21.729	5.2x	4.739	-11.277	2.7x
65sma-	6.080	-25.550	4.2x	5.804	-23.072	3.8x
Average						3.7x 4.0x
	5,729	-23,085		5,496	-20,979	

Remember that our projections are only approximations of what might happen, and no guarantee that losses will remain at or near this level. However, the method discussed in this section does provide an objective tool to plan for reasonable equity losses. You must rigidly enforce the risk control mechanism incorporated into the system tests, otherwise these forecasts are meaningless. Ideally, once we have protected the downside, the design of our system and future market action will take care of performance on the upside.

Changing Bet Size after Winning or Losing

One of the key money-management decisions you have to make is how you will change your bet size as your account equity evolves in time. Your trade-off is between equity growth and smoothness of the equity curve. This section presents some common "betting" strategies and their impact on the equity curve.

Two references will fill in the background on betting strategies. Bruce Babcock's book on trading systems examines different betting strategies. Jack D. Schwager's interviews with market wizards shows that many indicated that they reduced the size of their trades during losing periods. These references (see bibliography for details) should convince you that changing bet size can be as important as your system design.

The premise behind changing bet size is that you can use the outcome of the last trade to predict the outcome of the next trade. This implies that winning and losing trades come in streaks. However, it is easy to show mathematically that successive trades are independent. Hence, on average, it is difficult to justify the premise behind changing bet size. Despite this mathematical fact, most traders will tell you there are psychological benefits to reducing trade size during a drawdown. *You* can be conservative and assume losing trades will come in bunches, though winning trades may not. Under this assumption, you could generate a smoother equity curve by changing bet size.

A simulation will help us to examine the effect of different betting strategies on the smoothness of the equity curve. We will use the standard error calculations to have a uniform basis for the comparison. We chose ten trades at random, half of them winners, and sampled these trades at random to construct 14 sequences often trades each. On each sequence, we then tested the following four strategies:

1. Constant contracts: always trading two per signal.
2. Double-or-half: if the previous trade was a winner, trade four contracts. If the last trade was a loser, trade one contract.
3. Half-on-loss: if the previous trade is a loser, trade one contract. If the last trade was a winner, then trade two contracts again.
4. Double-on-loss: if the previous trade is a loser, trade four contracts. If the last trade is a winner, then trade two contracts again.

We started with $100,000 in each portfolio. Every strategy was tested on precisely the same trades. We ran 14 simulations, for a total of 140 trades, and then averaged the equity curves for each trading strategy. We compared the averaged curves for each strategy to the average curve for trading two contracts per trade. Finally, we used linear regression analysis to calculate the standard error.

You should conduct a larger simulation with your data to find the strategy you like. In particular, be aware that the double-on-loss is the riskiest strategy. If you are hit with an unusually long string of losses, this strategy will produce the largest drawdowns.

Table 7.13 shows the effect of changing the bet size after each trade. The strategy of halving trade size to one contract after each losing trade produced a 21.6-percent reduction in the standard error of the equity curve for only a 2.4-percent profit penalty. Thus, we got a substantially smoother curve for a relatively small reduction in profits.

Table 7.13 Effect of betting strategies on standard error of average equity curve

Strategy	Number of Contracts after	Number of Contracts after	Average Ending Equity	Percentage Change in Equity	Standard Error ($)	Percentage Change in
Constant	2	2	110,37	—	970	—
Half on	2	1	107,69	-2.4	760	-21.6
Double half	4	1	112.69	2.1	1.366	40.8
Double loss	2	4	115.74	4.9	1.488	53.4

The double-or-half strategy increased ending equity on average by only 2.1 percent, but the standard error increased by nearly 41 percent. You would expect this strategy to show sharp gains if winning trades come in bunches. Hence, the equity curve will be rougher and the increase in standard error is no surprise.

The double-on-loss strategy was the riskiest, as you can see by a more than 53-percent increase in standard error. The equity curve (see Figure 7.3) shows that this strategy can produce steep drawdowns. Although this strategy had the highest ending average equity, this was only 5 percent greater than the constant contract strategy. Hence, the relative risk reward does not seem worth the aggravation.

This limited simulation supports the opinion expressed by many accomplished traders that they like to reduce trade size during drawdowns. Table 7.13 clearly shows that the half-on-loss strategy had the best reward-to-risk performance. Some traders suggest that they defer accepting new signals during drawdowns, but ignoring new signals may cause you to miss just the signal you need to boost equity.

Table 7.13 shows that the fixed contracts strategy is also a reasonable choice. Certainly, when you are starting off, you may wish to consider this strategy to keep life simple. Eventually, as you feel more confident and have more equity, you can move on to other more elaborate strategies.

Note that when you use a fixed 2-percent stop to calculate a variable number of contracts, you are automatically adjusting position size to equity and volatility. If you have losing trades, equity will drop and bet size will decrease. Similarly, after profits, your bet size will increase. Hence, this strategy will produce a different equity curve. The calculations here should provide a starting point for you to explore other com-

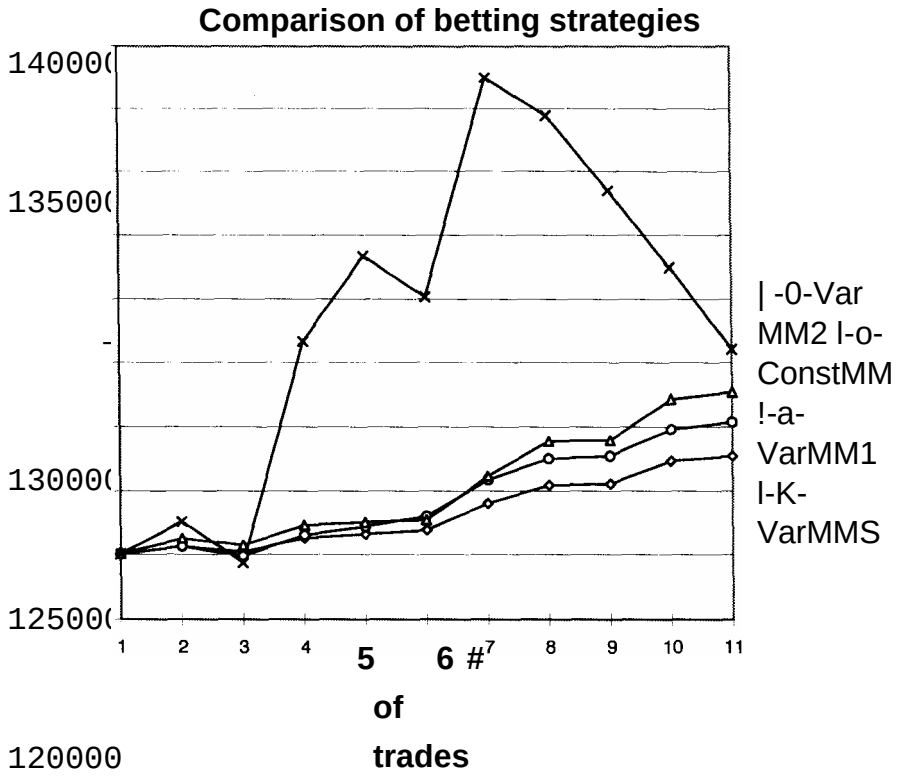

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Figure 7.3 Average equity curves for four betting strategies. The

"Const MM" curve is for a constant two contracts per trade. The "Var MM1" curve is for the double-or-half strategy. The "Var MM2" is for the half-on-loss strategy. The "Var MM3" curve is for the double-on-loss strategy.

plex strategies, such as continuously varying exposure during a trade. Ultimately, you are the best judge of the betting strategy that suits your style of trading.

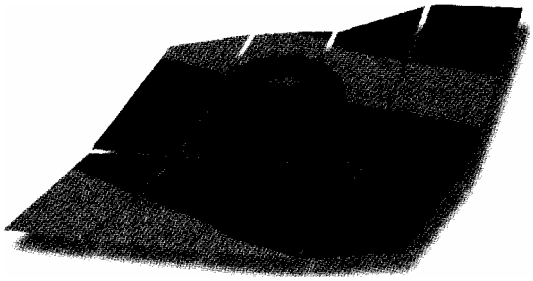
Summary

In this chapter we discussed key money-management ideas. We began by examining the risk of ruin. Those calculations show that there is little incentive to overleverage a trading account. The risk-of-ruin calculations assume that your bet size, payoff ratio, and fraction winners are fixed. However, you can vary bet size if you could identify an extraordinary opportunity in the markets.

We then looked at the interaction between system design and money management. The design philosophy is for you to protect the downside and let the market take care of the upside. We then used the standard deviation of monthly equity to project future drawdowns at four to five times the standard deviation.

We finished by looking at how betting strategies affect the smoothness of the equity curve. The fixed-contracts per signal is a reasonable choice for most traders. *You* can get a smoother curve by reducing position size after a losing trade. Your other strategies, such as double-on-win or double-on-loss, greatly increased equity curve roughness. *You* should understand this material well, because each of these money-management strategies can significantly affect future portfolio performance.

Chapter



Data Scrambling

There are never enough data of the kind you want.

Introduction

Our focus continues on understanding how our system will do in the future. In this chapter we introduce a new method to generate synthetic data that can produce unlimited amounts of data for system testing. The new method, called data scrambling, will help you overcome the restrictions imposed by the relatively small amount of data on futures markets. Data scrambling can create the new price ranges and new price patterns necessary to test your system under the widest possible range of market activity. This is true out-of-sample testing. We explain this procedure in detail using a spreadsheet and S&P-500 data. We then use a 7-year long Swiss franc continuous contract to generate 56 years of synthetic data. We then test a volatility system on the synthetic data so you can appreciate the advantages of such testing.

What You Really Want to Know about Your System

What you really want to know about your trading system is how it will do in the future. Ideally, you want to know what the profits and the drawdowns may be. Since you cannot foresee the future, a good option is to test your systems on many data sets that "simulate" future market

action. You can then simply average the results to get reasonable estimates of future profits and drawdowns. We emphasize, however, that it is difficult to get precise figures for both your profitability and your drawdowns.

You can also use good estimates for the average and standard deviation of the monthly equity changes. We looked at interval equity change and its standard deviation when we studied equity curves. The standard deviation is useful for projecting future drawdowns.

As a trader, you also want to get a feel for how well the design philosophy of a particular system works on a variety of markets. Your comfort level with a system's design approach is even more valuable than performance numbers because you can implement a familiar system without hesitation. One way to gain this confidence is to test the system on many different data sets, of the type you are *likely* to come across in the future.

Remember that all the computer testing occurs in a sterile, unemotional environment, without any great stakes riding on the outcome. You become emotionally involved with the system in real trading because the stakes are higher. However, you never feel this pressure when you test a system. A solution is to test the system on many data sets so you can experience, at least indirectly, many different market environments. You will then have a better understanding of the variability of system performance over those markets.

Note that your system-testing efforts tell you only how your system would have done in the past. Your results are hostage to the particular data set you use. So you would like to test dozens, even hundreds, of data sets that simulate future market action. However, since most of the active futures markets have traded for less than two decades, the amounts of market data are finite. Add the complication that futures contracts expire, and your big challenge is to find sufficient data to thoroughly test your system. The more data sets you can use, the better off you are, both from a quantitative and from a psychological perspective.

This chapter discusses a new method to generate unlimited amounts of data that "simulate" future market action. This new method allows you to generate an unlimited number of data sets from historical market data. These synthetic data encapsulate knowledge about market volatility and trading patterns. You will see that once you can generate such data, you are free to thoroughly test your system in a way better than ever possible before. What is more important, you can "live through" many types of markets, and build confidence in the system that could be vital to your success.

229 Past Is Prolog: Sampling with Replacement

The idea of sampling with replacement is basically as follows. Imagine a situation in which you take 100 disks, number them from 1 to 100, and then mix them up in a bag. You then shake the bag, and pull out a disk with, say, #21 on it. Now, before pulling out a second disk, you have two options. You can put #21 back into the bag so that all 100 disks are in the bag, or you can select another number out of the remaining 99 disks, without replacing #21 in the bag.

If you put #21 back, there is a 1 chance in 100 you will pull it out the second time. This is the process of sampling with replacement. The probability that you will get #21 the first time is 1 percent. The probability that you will get #21 twice is 0.01 percent. Thus, the probability of getting #21 three times in a row is 0.0001 percent, or once in 1,000,000 tries. Remember, just because the probability of getting #21 three times in a row is small does not mean it cannot happen.

An example will illustrate the idea behind sampling with replacement (see Table 8.1). Using the numbers from 1 to 10 as our "original" sample, we calculate its average (5.5) and standard deviation (3.03). We then use the sampling-with-replacement algorithm in Microsoft Excel 5.0 to generate 11 additional samples. If you study the samples for a minute, you will see that the same value often occurs more than once. The values are being drawn at random from the original sample, so that each of the 11 samples is different. At the same time, we retain the "signature" of the original data set, as measured by the difference between the highest and lowest value.

We have also computed the average and standard deviation for each sample. These values range from 4.30 to 6.90 for the average and 1.95 to 3.60 for the standard deviation. Thus, each sample is only a rough estimate of the average and standard deviation of the original sample. However, when we calculate the average (5.72) and standard deviation (2.81) for all 11 samples, those values are closer to the statistics of the original sample. The more samples we generate, the better our estimates for the statistics of the original sample.

Applying the same principle to system testing, we could use sampling with replacement to generate synthetic data. The extra data will improve our estimates of the average and standard deviation of, say, the monthly equity changes. The new data will allow true out-of-sample testing and extend the variety of market conditions exposed to the system.

Table 8.1 Illustrating sampling with replacement; note how the average and standard deviation of the 11 samples move toward the values for the original sample.

Original	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
1	7	2	8	3	9	6	2	8	6	1	7
2	6	6	9	6	10	7	8	10	3	4	3
3	2	3	6	4	1	8	4	1	4	1	0
4	3	7	7	10	5	9	1	8	6	6	5
5	10	3	7	10	7	9	10	7	8	5	4
6	9	6	3	8	7	10	4	10	10	8	3
7	5	4	5	1	3	3	10	6	5	6	3
8	5	7	3	10	9	2	6	9	7	8	5
9	4	1	8	2	3	10	9	4	2	4	8
10	5	7	8	4	7	5	1	1	1	9	2
Average	5.50	5.60	4.60	6.40	5.80	6.10	6.90	5.50	6.40	5.20	6.10
Stddev	3.03	2.50	2.27	2.12	3.49	3.00	2.85	3.60	3.37	2.78	2.73
Average (all)	5.72										
Std dev (all)	2.81										

The idea of sampling with replacement leads to another statistical idea, called bootstrapping, in which you use sampling with replacement from the results of some experiment to develop the statistical distribution for the quantity of interest. For example, say you had the results of 200 trades from a trading system. You can use sampling with replacement to generate different possible outcomes, and then average those data to develop a distribution for future trading results. In the example above, the different values of average and standard deviation from each sample give us a distribution for the average and standard deviation of the original sample.

You can revisit our discussion of the results for the 65sma-3cc system to look at the distribution of all trades. Those 2,400 tests led to a particular histogram or distribution of trades. We could use sampling with replacement from the 2,400 trades to develop other potential distributions or histograms, and try to estimate future performance.

One difficulty in using sampling with replacement is that we can select data only from within the original sample. Hence, you can "see"

only those events that have occurred in the original sample. The procedure developed here tries to overcome this problem so you can create new price ranges and price patterns.

Let us see how we can use sampling with replacement on a continuous contract to generate other continuous contracts that encapsulate market information. Once we can replicate market data, we are on the way to freedom from data set limitations.

Data Scrambling: All the Synthetic Data You'll Ever Need

Data from scrambled continuous contracts are termed synthetic data because these data are not from actual trading in the open market. The phrase data scrambling is used because this method randomly rearranges the data to create new sequences.

Let us first see how to encapsulate market information. We place two daily bars next to each other. Then, we observe the relationship between the open (0), high (H), low (L), and close (C) of the second bar by using the close of the first bar as the reference. We can write the relationship as follows:

deltaO = 0 - C[1],

dekaH = H - C[1],

deltaL = L - C[1],

dehaC = C - C[1].

Here [1] denotes the close of the previous day. These equations encapsulate market trading behavior since they capture price patterns versus the previous close. Over a period of years, each market will have some characteristic values for these equations, based on its volatility, liquidity, and other trading patterns. When we sample with replacement using these formulas, we create patterns that bear the market's signature as defined by relative price relationships.

The next step is to use a random number generator to scramble the bars. Once you have a new sequence, you need a starting point, usually the prior close. *You.* can use any number for the first bar. The new bar is derived from the prior close as follows (new synthetic values are indicated by the Syn prefix):

Syn-Close = Close [1] + delta **C,**

Syn-High = Close[l] + delta H,

Syn-Low = Close [1] + delta L, Syn-

Open = Close[l] + delta 0.

So the calculations are easy to put into a program or a spreadsheet. We will first calculate the interbar relationships in Table 8.2, which is based on the actual bar sequence of the December 1995 S&P-500 (Figure 8.1). The interbar relationships appear in the last four columns. The difference between the daily close of 11/30 and 11/29 was -0.80 points. The differences between yesterday's close and today's open, high, low, and close are shown for each day. These calculations encapsulate price relationships. Now we can scramble these bars using a random number generator.

To scramble these data, number them from 1 to *n*, where *n* is the last bar. Then, use the random number generator to pick a number between 1 and *n*. That number is the next bar in the sequence. Suppose on the tenth pick, you pick bar 5. Then the original bar 5 becomes bar 10 of the new sequence. The bars may repeat more than once. For example, on the twenty-seventh pick, you may draw bar 5 once again. You can generate as long a sequence as you desire.

Here we used the 11/29/95 close of 608.05 as reference, and generated a new sequence of bars using the sampling function in Microsoft Excel . The new sequence was: 4, 5, 8, 1, 3, 10, 10, 8, 9, 1. Therefore, starting with the previous close of 608.05, we put in the fourth bar of the original data, then the fifth bar, and the eighth bar, and so on.

Table 8.3, page 234, presents the spreadsheet used to calculate the new synthetic data. The first column is the bar number drawn by sam-

Table 8.2 Spreadsheet based on December 1995 SScP-500 data.

0-	H-	L-	C-Bar#	Date	Open	High	Low	Close	C[1]	C[1]	C[1]
				11/29/95	608.6	608.85		606.3	608.05		
1	11/30/95		608.07		610	606.1	607.25		0.02		
	1.95	-1.95	-0.8								
2	12/01/95		608	609.4	605.9	608.3	0.75	2.15	-1.35		
1.05											
3	12/04/95		608.87		615.5	608.05		614.8	0.57		
	7.2	-0.25	6.5								
4	12/05/95		614.02		619.5	613.85		618.75		-	
0.78	4.7	-0.95	3.95								
5	12/06/95		619.85		622.65		617.35		619.8		
	1.1	3.9	-1.4	1.05							

6	12/07/95	618.95	619.8	615.7	616.65	-0.85	0	-4.1	-3.15
7	12/08/95	618.5	619.5	614.3	618.3	1.85	2.85	-2.35	1.65
8	12/11/95	618.9	621.7	617.75	619.8	0.6	3.4	-0.55	1.5
9	12/12/95	618.9	620	618.2	618.8	-0.9	0.2	-1.6	-1
10	12/13/95	619.4	622.6	618.65	621.35	0.6	3.8	-0.15	2.55

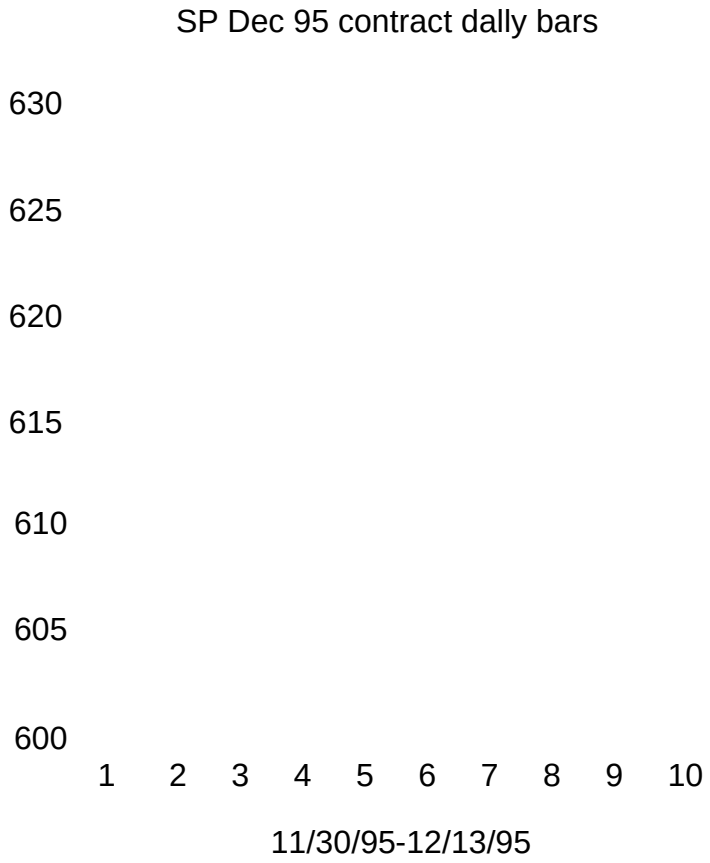


Figure 8.1 Actual price bars from the December 1995 SScP-500 contract.

pling with replacement. The next four columns are the inter-bar relations previous calculated for each bar in Table 8.2. The last four columns are the synthetic data derived from the previous close by adding the in-terbar relations.

In Table 8.2, the data for 12/05 converts to bar 4, and the market gained 3.95 points on the close. In Table 8.3, bar 4 is the first bar of the new sequence. The previous close was assumed to be 608.05. So the new close is 3.95 + 608.05, or 612.00. The new low is 608.05 - 0.95, or 607.10. The new high is 4.7 + 608.05, or 612.75. These are the numbers for the synthetic contract in the first row. The close for the second bar is 612.00 + 1.05 or 613.05. You can now complete the rest of the calculations. The new scrambled data created a synthetic bar pattern plotted in Figure 8.2.

The new bar sequence (Figure 8.2) shows an upward bias, getting up toward the 630 area. Note how it does not show the consolidation in the last six bars of the original data. The last bar from the original data (bar 10 on Figure 8.1) occurs in Figure 8.2 as bars 6 and 7, and you can see that the relative appearance of the high and low versus the previous

Table 8.3 Scrambled data for SSiP-500 using relationships calculated in Table 8.2. I assumed that the close before the first bar (bar 4 below) was 608.05.

Bar #	0-C[1]	H-C[1]	L-C[1]	C-C[1	Syn-0	Syn-H	Syn-L	Syn-C
4	-0.78	4.7	-0.95	3.95	607.27	612.75	607.1	612
5	1.1	3.9	-1.4	1.05	613.1	615.9	610.06	613.05
8	0.6	3.4	-0.55	1.5	613.65	616.45	612.5	614.55
1	0.02	1.95	-1.95	-0.8	614.57	616.5	612.6	613.75
3	0.57	7.2	-0.25	6.5	614.32	620.95	613.5	620.25
10	0.6	3.8	-0.15	2.55	620.85	624.05	620.1	622.8
10	0.6	3.8	-0.15	2.55	623.4	626.6	622.65	625.35
8	0.6	3.4	-0.55	1.5	625.95	628.75	624.8	626.85
9	-0.9	0.2	-1.6	-1	625.95	627.05	625.25	625.85
1	0.02	1.95	-1.95	-0.8	625.87	627.8	623.9	625.05

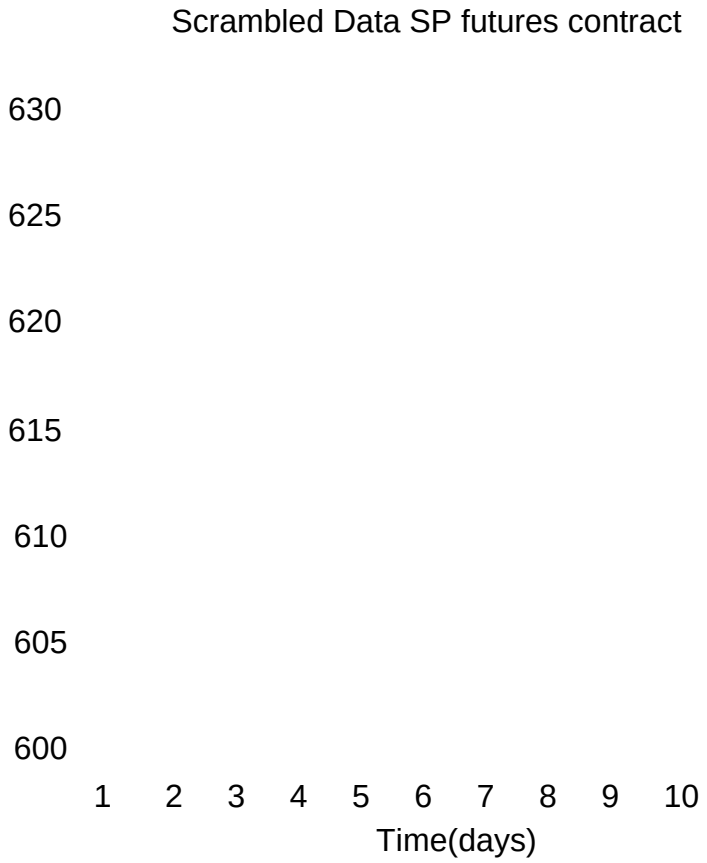


Figure 8.2 Synthetic data from Table 8.3 for the S&P-500 contract.

bar in the sequence is similar in both cases. Thus, we have encapsulated the market behavior in the original bar 10 and reproduced it in another sequence to create new synthetic data.

Of course, the more samples you generate, the greater the variety of patterns you will see. Another synthetic pattern derived from original December 1995 S&P-500 futures data is shown in Figure 8.3 to illustrate the variety of possible patterns. The new patterns cover a narrower price range than the original data, and appear like a breakout at the end.

Thus, you can generate a variety of chart patterns using data scrambling. Continuous contracts work well to create synthetic data because they represent a long history of market action. If you prefer, you can use this method on individual contracts, and then string them together for testing using rollovers at the appropriate dates.

The power of data scrambling increases as the number of bars of data increases because you can create a greater variety of patterns. Thus, if you had, say, a 5-year or 7-year long continuous contract, you could

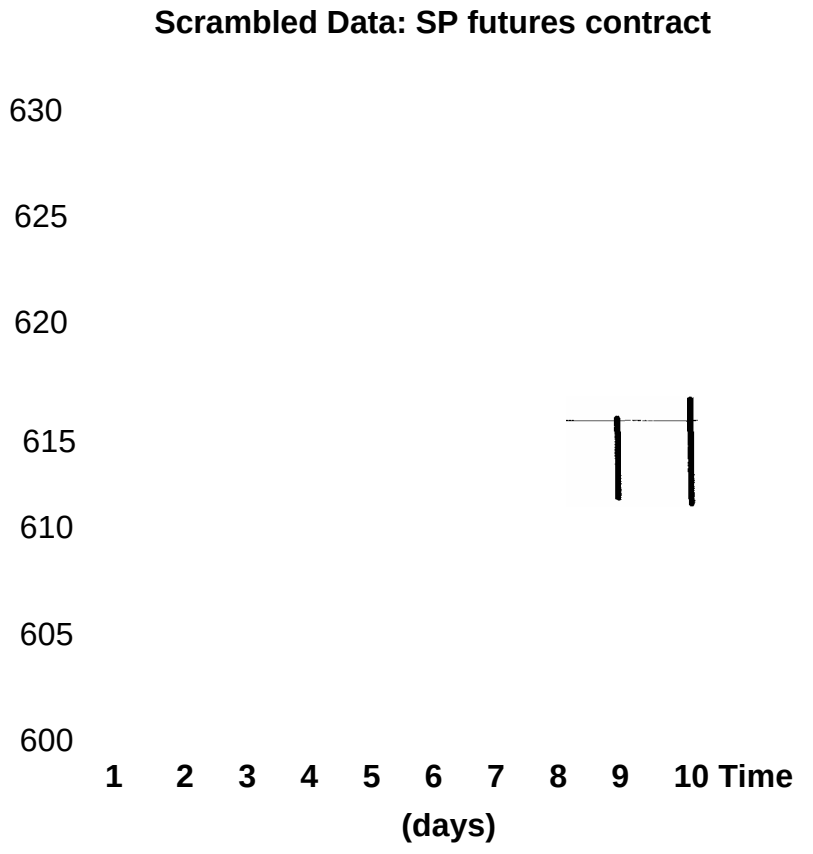


Figure 8.3 Synthetic data for S&P-500 contract using the bar sequence *6,* 5, 4, 2,1,9,10,8,7,3.

Figure 8.4 Swiss franc synthetic contract (lower curve) generated from daily data using continuous contract (upper curve).

generate 100 years of data and test your system against a variety of market conditions. Since these are the type of patterns you are *likely* to see in the future, this is the most rigorous out-of-sample testing you can achieve.

Figure 8.4 shows how data scrambling can overcome the limitation of insufficient data. First, the original data had several trading ranges, whereas the synthetic data has several trends, indicating you can generate new price patterns. Second, the synthetic data exceeded the price range of the original. Thus data scrambling can create new price ranges and new price patterns, which are necessary to test your system under the widest possible range of market activity.

Testing a Volatility System on Synthetic Data

Here we test a volatility system on synthetic data to illustrate how to use data scrambling. A volatility system is a good choice for this because the currency markets have recently seen sudden, compressed moves. *You* may feel that sudden, compressed price moves are a staple in today's futures markets. However, a historical review will convince you that they have also occurred before. Such moves are often difficult to trade with

systems that use heavily smoothed data. Many traders have observed that sudden moves also occur near the turning points of trends. Hence, you may find a volatility-based approach also suitable for identifying tops or bottoms. You can define volatility in many different ways.

The usual practice is to use some multiple of the recent true range to define the edges of price moves. Here we take a simpler approach and use just the difference between today's high and low as the measure of price range. The buy stop for tomorrow is today's high plus two times today's high-low range. Similarly, the sell stop is today's low minus two times today's high-low range. It is quite unlikely (but not impossible) that you will hit both entry orders on the same day.

The above definition of entry points is quite generic and not optimized to any specific market. You can use a multiple larger than two to get fewer entries, or smaller than two if you want more entries. We assume these volatile swings occur near turning points, so we will test an arbitrary trend following exit: exiting on the close of the twentieth day in the trade. First we look at test results using continuous contracts. Then, we will test this system on synthetic Swiss franc data obtained using data scrambling. The goal is to show how this simple system works as well as to illustrate how you can use scrambled data.

Figure 8.5 shows how the volatility entries appear on the December 1995 Swiss franc contract. In September, this system profited from a powerful rally. The exit at the end of 20 days got you out in the consolidation region. However, the system did not go short soon enough in the August sell-off. That trade was barely profitable. Note the previous long trade hit the $3,000 initial stop. Therefore, by design, a short burst out of one consolidation into another consolidation or trend works best with this system.

We tested the system first on a continuous contract using actual Swiss franc data from June 30, 1989, through June 30, 1995, allowing $100 for slippage and commissions and using a $3,000 initial stop. We then used the data scrambling routine to scramble these data, and made up eight more continuous contracts. We tested the same system without any changes on the scrambled data, as summarized in Table 8.4. The synthetic data have the letters "Syn" in their name for clear identification.

The results over 56 years of synthetic data show that it is possible to have future performance significantly better or worse than the test period. This should come as no big surprise. The performance over individual synthetic contracts varies widely. The average performance of all the eight synthetic series (last row), however, approaches the performance over the original test period (first row). This result is similar

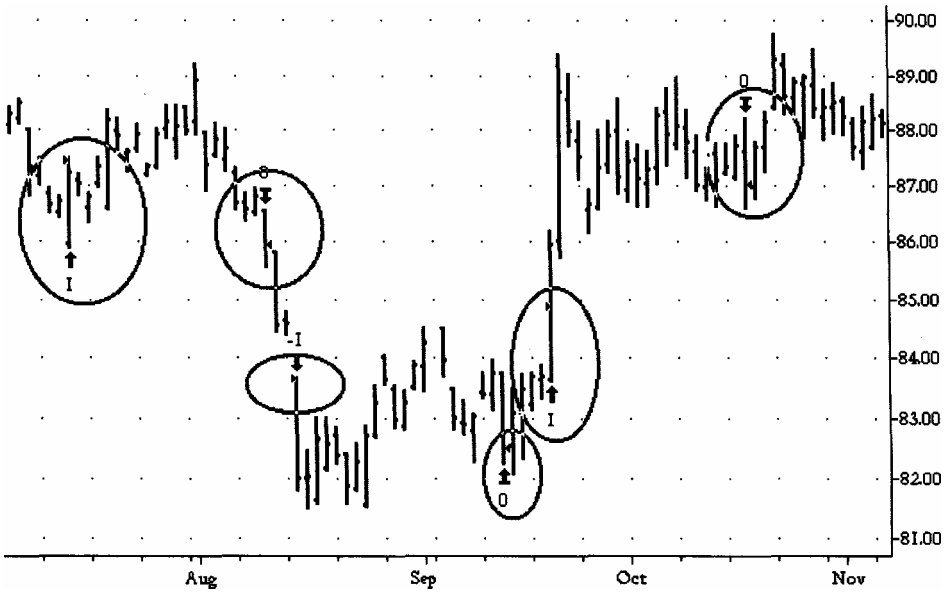


Figure 8.5 Stops at two times the high-low range above and below today's high and low provide good entries into compressed moves. However, the market can often make big moves without volatility.

Table 8.4 Comparison of volatility system on actual and scrambled data

Market	Profit ($)	Maximum Intraday Draw-down ($)	Factor	Number of Trades	Average Trade ($)	Number Win/ Loss	Average Profit Winners
SF	5,800	-17,600		43	1.06	121 1.92	48
Contract							
SF Syn	33.624	-12.732	1.42	81	39	1.60	415
SF Syn	35.563	-19.550	1.38	97	45	1.59	367
SF Syn	-713	-21.388	0.99	99	37	1.53	-8
SF Syn	14.350	-14.938	1.16	86	39	1.92	167
SF Syn	8.937	-20.425	1.11	98	44	1.36	91
SF Syn	-22.625	-27.050	0.79	101	40	1.21	-224
SF Syn	13.550	-22.463	1.14	97	42	1.49	139
SF Syn	-13,212	-30,750	0.9	97	42	1.19	-136
Average SFSyn	8,684	-21,162	1.11	95	41	1.49	101

to that shown in Table 8.1, where the average statistics of the random samples were close to the statistics of the original sample.

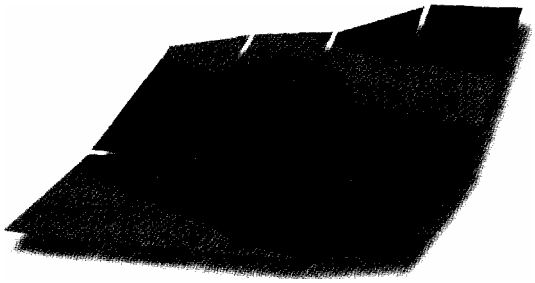
In essence, when we average the results over more and more synthetic data, we will get ever better estimates of the "true" or most likely system performance. We can also find the standard deviation of the results over synthetic data to quantify the variability of future results. For example, the standard deviation of the profits on synthetic data in Table 8.4 was $20,523 (not shown). Armed with this data, we can use mean-variance analysis to make portfolio decisions using the ideas of modem portfolio theory. We can try to find the portfolio weights for a group of systems that might achieve a given level of expected return for a particular expected standard deviation. We can also use the standard deviation to input a relevant range of values for risk of ruin calculations. Another application is to estimate a range of future drawdowns for a given system. Thus, synthetic data can be used to estimate the expected future performance.

There is one important limitation of scrambled data. Since we are using a random sampling with replacement approach, our new patterns do not represent actual market behavior. For example, synthetic data can create patterns that do not represent market psychology or any real supply-demand forces. Hence, you should create many data sets and average your system performance across those sets. The averaged performance will probably be more representative of potential system performance in the future.

Summary

In summary, scrambled data provide a new method to test a system over many different market conditions. *You* can observe the model's performance under such simulations, and gain much needed confidence on how it works and learn to recognize when it does not. You can then use your insight to create filters that may improve system performance, reduce the number of trades, and create a neutral zone for system trading. *You* can also develop equity curves to check your interval estimates of standard deviation and therefore improve your projections of future drawdowns. *You* can also perform a subjective evaluation of market conditions under which the system does particularly well or poorly.

Chapter



A System for Trading

A speculator's trade plan is often little more than greedy entries, hopeful risk control and fearful exits.

Introduction

Trading is analysis in action. If you thought building a trading system was easy, here comes the difficult part: implementing it. In this chapter we examine the factors you should consider when you implement your trading system. If you have followed all the principles outlined earlier, you have created a trading system that is just right for you. Now, all you have to do is to execute it. We will attempt to close the gap between system design and implementation. Hence, in this chapter we focus on a system for trading.

Surprisingly, there are only two steps necessary to implement a trading system: (1) you need to have a specific trading plan, and (2) you need to execute the plan. You will be surprised how easy it is to trade without a plan and without a system to monitor implementation.

The first hurdle you must overcome is that system testing does not solve all your problems. Second, you must understand something about your interaction with the markets when you start trading. Third, there are other key issues such as risk control and money management that need attention. Last, you need a tool to organize your trading.

The Problem with Testing

Even though trading occurs in a pressure cooker of emotion, testing is performed in an emotional vacuum. Imagine an aerodynamically slick race car designed in a wind tunnel that handles poorly in the turbulent wake of other cars on race day. Similarly, a high-performance system based on historical data can provide a bumpy ride in actual trading.

Your computerized system testing occurs unemotionally, without any fear of losing money. All you see are a summary of the results and colorful up or down arrows pointing out entries and exits. You do not have to suffer through losing streaks during testing. Nor do you have to agonize as the system is late to enter or slow to exit. You do not have to create orders, enter orders, track fills, remember rollovers, monitor margin, or read the daily equity run. What is more important, you do not have to actively monitor position risk or make any money management decisions.

During computer testing, you do not have any fear of losing money or missing opportunities. Thus, system testing using software is a sterile environment that fails to capture the emotional components of system implementation. Hence, if you use all your creativity to develop a trading system that considers all the factors we have discussed, then all you have to do is to focus on system implementation.

Trading is an acquired skill. Perhaps the only way to acquire and maintain a new skill is to endure endless repetitions. Computerized testing does not allow you to build any skills in implementing the system. Thus, no amount of testing can give the repetitions needed to develop the many skills necessary to physically implement a system. Clearly, you need some more tools to address these key limitations of system design and testing.

Paper Trading: Pros and Cons

A traditional answer to the limitations of system design is to use a trial period during which you trade the system "on paper." Paper trading will certainly help you address and understand the mechanics of actual trading. You can practice all the steps of implementing the system, such as creating portfolios, generating orders, tracking fills, monitoring risk, and scoring profits and losses. In addition, you can keep a diary of your emotions, which is very useful to track your trading beliefs and patterns.

Another valuable way to use paper trading is to analyze your system results trade by trade. *You* should try to relive the trades, scanning through the chart one day at a time, writing your reactions to chart patterns, equity levels, volatility, and so forth. Even though this is not a perfect solution, reviewing historical trades in detail will give you valuable insight into system performance. The extra insight will enable you to deal with the ups and downs of the system in actual trading.

However, paper trading does not tell you much about actual system performance. Thus, you will gain little additional insight into system performance that you have not already gleaned from system testing. Let us assume that during testing your system produced eight successive losing trades. If the system produces three successive winning trades during paper trading, this does not mean it is a great system. Similarly, if it generates ten successive losing trades, it does not mean it is a useless system. Precisely because successive trades are unrelated, you cannot use the results observed in paper trading to make sweeping generalizations about overall system performance.

Another disadvantage of paper trading is that it still lacks the fear of losing that afflicts trading with real dollars. Thus, paper trading can still insulate you from the emotional demands of real trading. In spite of these limitations, paper trading offers a reasonable means to close the gap between system design and implementation.

Do You Believe in Your System?

The market will challenge your faith in your system in every way possible. The market uses the well-known maxim of war: "Lure them with greed, conquer them with confusion." The markets will constantly create new chart patterns that can confuse your analysis. Unless you have absolute faith in your system, the markets will push you to meddle with your system. They will push you to override your signals, alter your plans, bend your system rules, invent new exceptions—all in the name of "improving performance." The only place to improve system design is with rigorous back testing and prospective paper trading. Any untested deviation provides short-lived gratification, which can seriously erode long-term performance.

You should pour all your creativity and emotional needs into creating a system that works for you. Your system should have the time horizon, trading frequency, market sensitivity, and profitability that you consider essential. Once you have rigorously tested the system on historical

data, you should test it on scrambled data. You will quickly discover the type of markets the system likes and dislikes when you test it on scrambled data. You will also have greater confidence in the system's future performance by testing it over many sets of scrambled data. You can follow up system testing with paper trading to clarify the mechanics of the process. Once you are satisfied that this is the system you want, you should resist all unchecked attempts to modify it.

The markets push you to reexamine your faith in your system. You should not use a system unless you can reaffirm your full faith and confidence in that system every day. If you do not believe in your system, the market will quickly push you into deviating from it. Once you deviate from a system, you are trading an untested system, and all bets are off. Of course, you can ask why you should stick to a tested and true system. The answer is found in the next section.

Time Is Your Ally

The market giveth, and the market taketh away. You should recognize that in all markets, there will be time periods when money is easily made and other periods when most models will show losses. Your goal, as a system trader, is to survive the unprofitable periods so you can enjoy the good times when they roll around. In essence, your risk-control strategy, money-management practices, and overall system design will all play major roles in determining your ability to survive difficult market conditions. Hence, it is advantageous to take the long view and remember that the current trade is just one of many to come. Therefore, you need not get emotionally involved in the outcome of each trade.

Suppose you are trading many markets and more than one system in a diversified trading account. Let us assume that your average probability of winning is 35 percent. Since we can show that successive trades are independent, the probability of having ten successive losing trades is $(0.65)^{10}$, or 0.0135, or 13 in 1,000. Thus, if you opened 1,000 new accounts, only 13 of them would show ten successive losing trades. Now, suppose you put on the trades all at the same time. If you risked 2 percent per trade, you will experience a 20-percent drawdown at the very beginning about 13 times in 1,000 attempts. If you risked 1 percent per trade, your chance of reaching a 20-percent drawdown is approximately 18 in 10,000.

A 20-percent loss of capital, although not pleasant, is not irreversible. You should also recognize that unlikely events can and do

occur. Thus, do not get emotionally involved in each gyration of every trade. *You* should take the long view: enforce rigid risk control, follow money-management guidelines, and focus on implementing your system.

No Exceptions

A good way to assure long-term success is to follow your system without exceptions. If you want exceptions, write them down and test them thoroughly instead of relying on your intuition alone. If you want to override your model, it probably means you are not comfortable with it and should do more testing and refining.

Many traders will use rising volatility as a measure of impending market change. They will reduce their positions when volatility is "high." You should define this scenario precisely. For example, you could say that volatility is "high" if the 50-day standard deviation of closing prices is more than $1,500. Then, you could test historical price data to check what the markets have done when volatility has risen to this level.

You could choose to increase market exposure to 4 percent of account equity if conditions are "right." Instead of relying on intuition, you could define a specific condition as "right," such as a 2 5-bar breakout accompanied by a 5-day RSI value greater than 70 or less than 30. You can then check historical data and develop some statistics on what to expect.

We saw in the tests with the 65sma-3cc model in chapter 4 that only 4 percent of the trade were the home runs that made all the difference in portfolio performance. If you routinely deviate from your system, there is no assurance that you will not manage to miss all the important trades in a given period.

The no-exceptions policy is necessary for another reason: traceabil-ity, which is discussed in the next section.

Full Traceability

You should be able to trace back in time the precise reasons for a particular trade or trading action. For example, you should be able to recall why you made a particular trade or move. If you have a well-defined mechanical system, and you follow a strict policy of no exceptions, then you have assured traceability.

If you use subjective chart analysis, then the best way to understand your trading patterns is to keep a diary and a copy of your charts. You should record all the emotions and analyses you used to make a certain decision.

If you have no traceability, you will have little information to monitor your implementation, and you will lose valuable information that could improve your trading. Let's assume you have a tendency to get in late and get out too soon. If you do not keep detailed records, it is difficult to correct such tendencies. If you have good records, you can calculate the impact of your late entries and early exits. Specifically, you can determine the type of market conditions that push you into exiting early. Say you find that a sharp 3-day sell-off often pushes you to exit your trades. Then, after a brief consolidation, the markets have resumed their previous trend. You now have reliable information you can use to overcome your fear that every 3-day countermove is going to escalate into a major correction.

Traceability is also important if you notice errors in your account statements and want to get them corrected. For example, your broker may fail to report a fill, or give you a fill far away from your desired prices. If you have good records, it is relatively easier to make the changes you desire. If you called in to check a fill and were given a certain fill price, but your equity run shows a different fill price, or worse, does not show a fill at all, you can correct such mechanical errors if you keep good records.

"Guaranteed" Entry into Major Trends

Over the long run, your overall performance will be greatly influenced by less than 5 percent of your trades. You only have to miss a few big trades to seriously degrade overall performance. Your entry method and trade implementation should be focused on ensuring entries into the major trend. If one does not have a position in a particular market, that seems to increase the odds for the onset of a major trend.

When you design your system, try to use orders that will ensure you an entry into the desired trade. For example, an order to trade at the market, trade on the open, trade on the close, or trade on a stop will usually get you into a trade. Of course, the amount of slippage will vary, but if you are not doing great size, you will consistently enter the trade. If you rely on limit orders, you could easily miss a major trading opportunity by a few ticks. The cost of a lost opportunity is often greater than

the few ticks you save using a limit order. However, if you are trading liquid markets and have a real-time data feed, you could try to fine-tune your entries. But for most traders, an order entered with a broker seems to work best.

The greatest slippage occurs not in the markets, but at the source: with the trader. If you fail to place an order, or place a wrong order, or place the order incorrectly, then these errors will often cost you more than any slippage in the markets. Hence, you should strive to control slippage at the source. The no-exceptions policy will help to reduce slippage at the source.

It is a good idea to prepare an order entry sheet the previous day, and transmit it to your broker before the markets open. There are many advantages to preparing your orders when the markets are closed.

(1) You can create your order entry sheets calmly and unemotionally. (2) You can stick to your trade plans and avoid deviations. (3) You can double-check your orders for mechanical errors. (4) You can avoid trades made at the spur of the moment, without detailed analysis. (5) If you do plan subjective trades, you can write down detailed entry points or exit points, or other cues for trading. *You* can ensure entries into major trends by preparing your orders in advance and entering them before trading begins for the day.

Starting Up

When you begin trading your account for the first time, you must resolve some "start-up" issues. Let us assume you are using a mechanical system, and trading 20 markets. The first question is how to put on trades to match existing positions of your trading system. For example, the last signal in deutsche mark may be a buy signal that occurred 15 days ago. Now, should you put on the long position, or wait for a new signal? You may not want to wait for the next signal if your system trades infrequently. Another reason to put on the trade immediately is to capture the remainder of the current move. There are several ways to resolve this issue. (1) You can trade just one contract instead of multiple contracts. If you usually trade ten contracts, you can initiate your position with just one or two contracts to enter the position cautiously. (2) You can scale into the position. For example, you would buy ten contracts gradually over the next 5 days. (3) You can wait for the last day of the month and put on the entire position on the close. The benefit of putting on the position on the last trading day of the month is that then

the month-to-month equity changes will accurately reflect the actual system results.

You must also decide where to place your initial stop on a start-up trade. You can go with the usual initial stop at 1 or 2 percent of account equity. Your other option is to set it slightly wider than usual, but trade a proportionately smaller number of shares.

Risk Control

It is essential that you always maintain rigid risk control. Your risk control strategy may be entering a stop-loss order every day, and with each new position. You can also use more elaborate strategies around market correlation and volatility. The key is to always control your risk. Risk control and money management go together. Using good money management guidelines will place reasonable limits on position size and promote diversification. These will prevent one bad trade from wiping out your account.

Do You Have a Plan?

You should avoid trading without a plan. A common cause for trading problems and failures is the lack of a trading plan. *Your* trading plan should explain clearly how you will trade. You must specify the markets, number of contracts, type of orders, entry rules, exit rules, and risk-control rules. The more specific you can be, the easier it is to implement the plan. If you have specified and designed your system properly, defining and implementing a plan should be relatively easy.

Every football team makes elaborate plans for their games. For example, one championship football team would "script" the first 15 plays for every game. After careful research, the coaches would pick the first 15 plays ahead of time. Then, the players would practice these plays many times so that they all knew them well. On game day, every one could concentrate on executing those plays, with excellent results. This example points out the benefits of preparation. You can plan your trades, visualize how you will execute those trades, and then monitor how you executed the trades. This process of auto-feedback can help you improve as a trader.

You should plan for adversity. For example, are you ready to absorb a 20-percent drawdown in equity? Do you have a plan to cope with this sort of drawdown? For example, you may not be prepared to experience a 20-percent drawdown in the first 3 months of your trading. If such losses occur, would you modify your trading system, change your money-management and bet-size algorithms, or change the portfolio mix? Similarly, if you are up 20 percent, will you alter any of the same variables?

Scenario planning is common in the military across the world. You, too, should use your imagination to explore good and bad scenarios about your trading. You can then develop detailed plans that will help you cope with the ever-changing markets.

How Will You Monitor Compliance?

It is one thing to have a plan, and another to actually implement it. You cannot properly implement a plan if you do not have a way to monitor and record how well you are implementing your plan. A good way to measure compliance is to keep a daily diary. An electronic diary is a fast and easy way to record your compliance or deviations. Later, you can analyze the diary entries to measure how well you are executing your plans. You can also find out which elements are easy or difficult for you to implement. You can then work to strengthen your weak spots.

If you do wish to deviate from your system, write down your reasons in detail, and then test them rigorously. That is the best approach to ensure consistent, long-term performance. Let us suppose there is a news event or political development that suggests you should exit the position. You should observe a noticeable market reaction to such events, such as a gap, a large range day, an outside day, or a key reversal day. You can then identify such bars on daily data and test them systematically. This will give you a historical database to formulate your strat-

sgy-

Get It Off Your Chest!

One big plus of keeping a diary is that you can get your concerns off your chest simply by writing them down. Let us say you wanted to apply the ideas of total quality management or continuous improvement to

your trading. *You* must have detailed records of your trading, including how your orders were generated and what factors affected your implementation. *You* can keep a diary to get rid of any bottled-up emotions resulting from trading. A diary will add to the full traceability we discussed above by providing data on your emotional state.

Focus on Your Trading

It is difficult to avoid distractions and to focus sharply on your trading. Focus means you can execute your system without deviations. Focus means you can enter your orders, follow your risk-control guidelines, and reduce variations from your system. If you have a plan and a system you believe in, it is easier to focus on your trading. *You* should try to automate your analysis and order generation as much as possible. This will minimize variations from your system. Try to develop a routine that includes checking account equity, fills, new orders, rollovers, trailing stops, market volatility, and so forth.

The best way to focus on your trading is to separate analysis from trading. *You* should set aside a fixed time each day when you generate your trading sheets. You should try to be relaxed when you are generating your sheets. *You* should avoid circumstances that affect your concentration, since it is easy to make a mistake in your order entry process.

Trading with Your Head and Heart

Every trader has an analytical part (head) and an emotional component (heart). A system that suits you will engage both aspects of your personality. When you start trading a system, you face two expectations. One is the statistical expectation, which we have discussed in detail. The other is your emotional expectation from the system. If the two expectations are not coherent, then you will not be happy trading the offending system.

This raises questions about why you trade. For many people, the only reason to trade is to make a profit. However, you could have many other reasons, such as the excitement of trading or the intellectual challenge of competing with other traders. You should check to see if the following are consistent: your profit objective, trading horizon, mathematical expectations, and emotional expectations.

If these are not consistent, then you may not have the mental edge. Probably fewer than 25 percent of traders have the mental edge, and perhaps only 2 percent can maintain the edge year after year.

There are many contradictions between mathematical and emotional expectations. The mathematical expectation covers 2 to 3 years of data, but the emotional expectation covers only 2 to 3 months. Emotional expectations can be complex, and they cannot be represented by a single number. In the worst case, a system could have a positive mathematical expectation but a negative emotional expectation. In this case your head and heart disagree, and the inevitable tension will make it impossible for you trade this system.

Your emotional expectations may be based on an inaccurate or incomplete understanding of system test results. You should make it a point to study the evolution of each trade day by day. You should be comfortable with the dollar amount of the average trade, the winning percentage, and the length of the average trade. You should also be comfortable with the dollar amount of the initial risk-control stop. If you understand the "signature" of the system, then each trade will reinforce your belief in the system. If you have unreasonable emotional expectations, then each trade will diminish your faith in the system.

You may expect big successes, with few losing streaks and many exciting trades. The reality is that only 5 percent of the trades are big successes, you can have many losing streaks, and most of the trades are dull. You can use the "rule of two," as follows, to modulate your emotional expectations:

1. Expect half as many winning trades in a row as you project from your testing.
2. Expect twice as many losing trades in a row as your testing may show.
3. Prepare for half the expected profits.

Let us continue with the "head and heart" analogy. What you "think" you believe is in your head. What you "truly" believe is in your heart. *Your* head may be clear or confused. *Your* heart may be confident or fearful. If your head and heart disagree, and the stakes are low, then the head wins any conflicts. However, if the stakes are high, then the heart wins any conflicts. Thus, you can trade comfortably only if your head and heart agree. So spend the time and effort to understand system performance so that your mathematical and emotional expectations will agree. This is the key to long-term success.

Summary

You should integrate all the ideas of this chapter to create a system for trading. A trade plan is at the heart of a system for trading. *You* should monitor compliance with your plan and try to provide full traceability. You should also follow the principle of no exceptions to your trading rules. To win, trade with your head and heart.

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